Corporate Climate Resilience Innovation Among Malaysian Energy Firms: Evidence From CCRASI

Noor Raida Abd Rahman[1,4], Maslinawati Mohamad[2], Hairul Suhaimi Nahar[3] and Nor Hasimah Johari[4]

[1]Universiti Tenaga Nasional, Selangor, Kajang, Malaysia
[2]Universiti Teknologi MARA, Kampus Puncak Alam, Selangor, Malaysia.
[3]College of Business Administration, Tabuk University, City of Tabuk, Kingdom of Saudi Arabia.
[4]UNITEN Business School, Universiti Tenaga Nasional, Putrajaya Campus, Jalan Kajang, Malaysia

norraida@uniten.edu.my
masli856@uitm.edu.my
hbinnahar@ut.edu.sa
Hashimah@uniten.edu.my

Abstract: Climate change is forcing organisations to innovate their governance structures, risk management practices, and strategic decision-making processes to address the growing physical and transition risks associated with a changing climate. Within the energy sector, corporate climate resilience has emerged as an organisational innovation capability that enhances long-term competitiveness, strengthens responsible business practices, and creates sustainable value. Despite increasing regulatory expectations and sustainability reporting requirements, empirical evidence on how firms in emerging economies develop and embed climate resilience remains limited. This study assesses the level and evolution of corporate climate resilience among Malaysian energy firms using the Climate Change Risk and Adaptation Strategies Index (CCRASI), a multidimensional framework comprising 64 indicators across four dimensions, (i) climate risk assessment, (ii) adaptation strategies, (iii) carbon risk management, and (iv) governance and stakeholder engagement. Using content analysis, the annual and sustainability reports of 28 publicly listed Malaysian energy firms covering the period 2019-2024 were analysed. The results indicate a moderate level of corporate climate resilience, with an average score of 44.85%. However, resilience performance improved substantially during the study period, increasing from 25.06% in 2019 to 68.86% in 2024, representing an overall improvement of approximately 175%. Governance and stakeholder engagement recorded the highest score (59.55%), reflecting stronger board oversight, climate governance, stakeholder engagement and organisational accountability. In contrast, climate risk assessment recorded the lowest score (36.88%), indicating limited adoption of advanced practices such as quantitative climate risk assessment, climate scenario analysis, stress testing, and financial impact analysis. Carbon risk management and adaptation strategies also recorded moderate scores, suggesting that firms have made steady progress in strengthening carbon reduction initiatives and operational adaptation measures. This study contributes to the innovation and entrepreneurship literature by positioning corporate climate resilience as a strategic organisational innovation capability that strengthens organisational adaptive capacity, supports responsible business practices, and promotes sustainable value creation. It also demonstrates the applicability of the CCRASI as a practical assessment framework for evaluating organisational resilience and supporting continuous improvement. The findings provide practical guidance for business leaders and policymakers seeking to strengthen climate governance, improve organisational resilience, and accelerate the transition towards a competitive, low-carbon economy.

Keywords: Climate Governance, Climate Resilience, Climate Risk, Corporate Adaptability, Energy Firms, Sustainable Development.

1. Introduction

Climate change has emerged as one of the most significant challenges facing the global energy sector. According to the Intergovernmental Panel on Climate Change (IPCC, 2023), the frequency and intensity of climate-related events, including floods, heatwaves, droughts, storms, and sea-level rise, have increased considerably in recent decades. Such events pose significant risks to energy infrastructure, operational continuity, and energy security. At the same time, energy firms must also respond to increasing transition risks arising from evolving climate regulations, carbon pricing mechanisms, technological innovation, and rising stakeholder expectations associated with the transition to a low-carbon economy. Furthermore, the Sixth Assessment Report by the IPCC highlights that climate impacts and cascading risks disproportionately affect organisations with weak governance structures and limited adaptive capacity (IPCC, 2022). Against this backdrop, climate resilience is increasingly recognised as a strategic capability that enables firms to innovate, enhance organisational sustainability and remain competitive in an increasingly carbon-constrained business environment.

The energy sector is pivotal to the economic and social development of Malaysia and still the main source of greenhouse gas (GHG) emissions. It is therefore an important sector for the country's decarbonisation and transition to cleaner energy. Recent initiatives like the National Energy Transition Roadmap (NETR), Bursa

Malaysia Sustainability Reporting Requirements, and the National Sustainability Reporting Framework (NSRF) have increased the bar for firms to enhance their climate governance, climate-related disclosures, and their resilience to climate-related risks. This is in line with global trends, as investors, regulators, and financial institutions increasingly demand more transparency regarding climate-related risks and opportunities (Garrido-Merchán et al, 2026). In addition, climate-related risks are increasingly integrated into corporate risk management and strategic decision-making encouraging firms to adopt more responsible business practices and innovative governance approaches (Kumarasiri et al, 2026).

Despite growing interest in responsible business practices and corporate sustainability, limited empirical evidence exists on how Malaysian energy firms strategically develop climate resilience as part of their long-term organisational innovation capability and business sustainability. Much of the existing research has concentrated on areas like sustainability reporting, carbon disclosure, environmental performance, and climate-related governance. However, there has been a noticeable lack of attention to assessing firms' overall resilience to climate-related risks (Kumarasiri et al, 2026). Additionally, previous studies tend to look at individual aspects of climate management in isolation, providing limited insight into the multidimensional nature of organisational resilience, adaptive capacity, and climate preparedness (Lyle et al, 2026; Saha et al, 2026). Recent findings indicate that effective climate resilience assessment requires the integration of multiple dimensions to capture organisational preparedness, vulnerability, adaptive capacity, and risk management capability more comprehensively. As a result, there remains a lack of evidence regarding the extent to which energy firms are prepared to identify, manage, and adapt to climate-related risks.

To address this gap, this study aims to evaluate climate resilience as an indicator of responsible business practice by assessing how Malaysian energy firms integrate climate governance, risk management, adaptation strategies and stakeholder engagement into their sustainability strategies. For this purpose, we introduce and employ a multidimensional climate resilience index, so-called, the Climate Change Risk and Adaptation Strategies Index (CCRASI). This index comprises climate risk assessment, adaptation strategies, carbon risk management, and governance and stakeholder engagement. Unlike earlier research that mainly zeroes in on climate disclosure, carbon reporting, or governance mechanisms, this study offers a more comprehensive assessment of how well firms are equipped to recognise, manage, and adapt to climate-related risks. Specifically, the study assesses the current level of climate resilience, tracks its development from 2019 to 2024, and pinpoints the strongest and weakest dimensions of climate resilience among Malaysian energy firms.

2. Methodology

This study employs a quantitative content analysis approach to assess the climate resilience practices of Malaysian energy firms. The study utilised a sample of 28 energy firms listed on Bursa Malaysia from 2019-2024, comprising 168 firm-year observations. Data were collected from the annual and sustainability reports sourced from Bursa Malaysia and corporate websites. We employed the CCRASI to assess climate resilience, consisting of 64 indicators distributed across four dimensions: climate risk assessment, adaptation strategies, carbon risk management, and governance and stakeholder engagement. The CCRASI was developed from existing literature on climate resilience, climate risk management, sustainability reporting, and climate adaptation. Its multidimensional framework reflects contemporary perspectives that conceptualise organisational resilience as a multifaceted capability requiring the integration of multiple risk and resilience dimensions (Lyle et al, 2026; Saha et al, 2026). To evaluate climate resilience practices, this study adopts an unweighted index methodology, where each indicator is assigned equal importance. Each disclosed item receives a score of one (1), resulting in a maximum possible score of 64. The overall CCRASI score is then expressed as a percentage, with higher scores indicating stronger climate resilience practices and greater organisational readiness.

3. Results and Discussion

3.1 Overall Climate Resilience Performance

The mean CCRASI score is 44.85%, indicating that energy firms in Malaysia exhibit moderate resilience to climate change. Scores varied from 0% to 100%, with a standard deviation of 29.24, signifying substantial variation in climate resilience practices amongs firms. This moderate score aligns with recent evidence that organisations vary in their levels of readiness, adaptive capacity, and climate risk management capabilities, mainly due to their specific resources, governance structures, and strategic priorities (Lyle et al, 2026; Saha et al, 2026). The wide range of scores suggests that climate resilience practices are not uniformly adopted among energy firms, and

the degree to which climate-related risks are integrated in organisational decision-making differs significantly. These differences may be due to the different levels of organisational commitment and technical expertise and the extent to which climate-related risks are embedded in governance and enterprise risk management systems (Kumarasiri et al, 2026).

3.2 Trend of Climate Resilience Performance

The findings indicate that Malaysia's energy firms have substantially enhanced their climate change resilience practices throughout the study period. Figure 1 illustrates that the average CCRASI score increased from 25.06% in 2019 to an impressive 68.86% in 2024, signifying a total increase of approximately 175%. From 2020 and 2022, climate resilience strategies and risk management practices accelerated. This progress is expected to be propelled by heightened awareness of climate-related risk, rising stakeholder expectations, better practices in sustainability reporting, and greater support from national and international policy toward climate action and energy transition initiatives.

The persistent rise in CCRASI scores throughout 2023 and 2024 indicates that climate resilience has transcended mere compliance and is increasingly integrated into organisational governance, strategic planning, and operational decision-making processes. This improvement shows that energy firms are increasingly aware of the importance of tackling both physical and transition risks posed by climate change, thus facilitating wider decarbonisation and energy transition objectives.

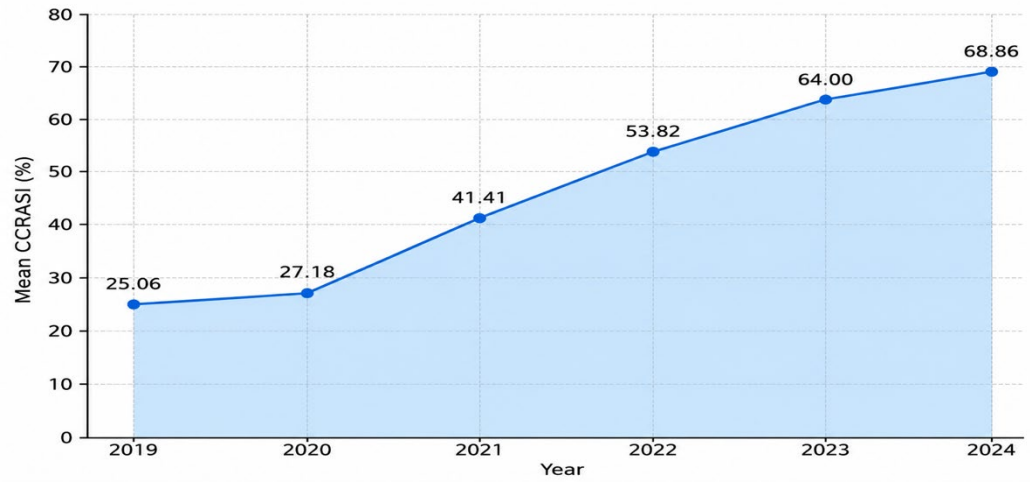


Figure 1: Trend of CCRASI Scores (2019–2024).

These results indicate a gradual yet significant enhancement of climate resilience capabilities among Malaysian energy firms. The upward trend indicates improvement across the four CCRASI dimensions: climate risk assessment, adaptation strategies, carbon risk management, and governance and stakeholder engagement; signifying a more proactive and strategic response to climate-related challenges. Furthermore, these findings provide valuable insights for the execution of NSRF by pinpointing deficiencies in climate resilience practices that necessitate enhanced focus in disclosure, monitoring, and strategic management.

3.3 Analysis by CCRASI Dimension

Figure 2 displays the average scores for the four dimensions of CCRASI for Malaysian energy firms during the period 2019-2024. The findings indicate significant variability across these dimensions, suggesting that the advancement of climate resilience practices is inconsistent throughout all aspects of climate risk management.

Governance and stakeholder engagement emerged as the strongest dimension, recording the highest average score of 59.55%. This finding suggests that most Malaysian energy firms have established climate-related governance structures, board oversight mechanisms, sustainability policies, and stakeholder engagement initiatives. The relatively high score reflects the widespread integration of climate considerations into corporate policies and enterprise risk management, supported by regular climate-related reporting to the board, dedicated climate leadership, board training, and internal awareness programmes. Collaboration in enhancing national climate adaptation and mitigation initiatives is growing, evidenced by partnerships with governmental bodies.

These practices reflect the rising incorporation of climate governance into corporate management and strategic decision-making.

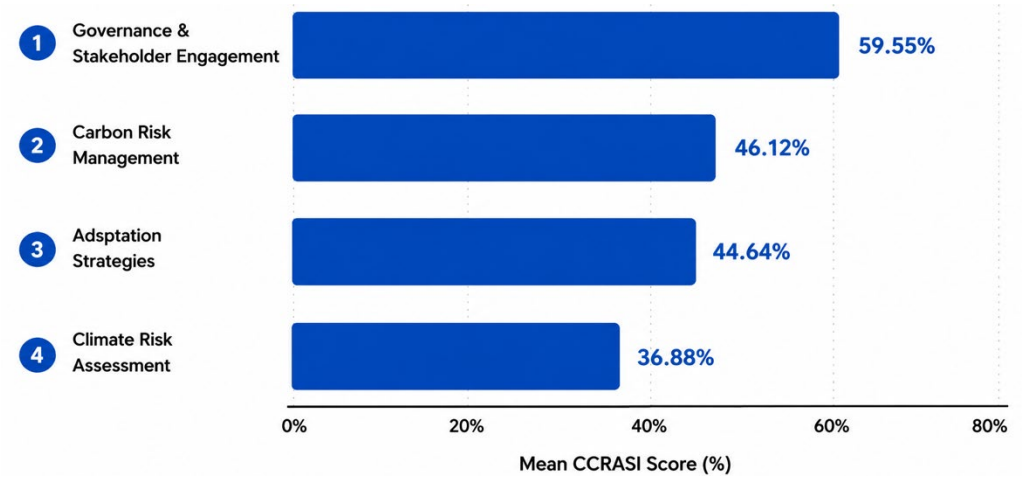


Figure 2: Average CCRASI Dimension Scores among Malaysian Energy Firms (2019–2024).

This evolution signifies that climate governance is increasingly becoming a strategic business practice instead of a mere reporting obligation, indicating a deeper integration of sustainability into corporate decision-making. The heightened score signifies a growing emphasis on climate accountability, transparency, and sustainability governance among Malaysian energy firms. The significant performance of this dimension likely reflects the growing impact of global climate-related reporting frameworks, including the Task Force on Climate-related Financial Disclosures (TCFD) and the International Sustainability Standards Board (ISSB). These frameworks are prompting companies to strengthen their governance frameworks and refine climate-related disclosures. As investors and regulators increasingly prioritise climate-related information, companies are under intensified pressure to demonstrate accountability in managing climate-related risks (Garrido-Merchán et al, 2026). The discovery aligns with prior studies indicating that climate-related and ESG disclosures can reduce information asymmetry and bolster stakeholder confidence (Perera et al, 2026). This interpretation is further supported by evidence indicating that climate-related reporting often emphasises governance, oversight, and disclosure mechanisms, as these elements are more readily articulated and face increased regulatory scrutiny (Saha et al, 2026). As a result, companies typically perform better in governance-related aspects than in technically challenging fields like climate risk evaluation and long-term adaptation strategies. This might explain why governance and stakeholder engagement scored the highest, whereas climate risk assessment lagged behind as the weakest dimension in the CCRASI framework.

Carbon risk management ranked second, with an average score of 46.12%. This suggests that Malaysian energy firms are increasingly strengthening carbon management through the measurement of Scope 1 and Scope 2 GHG emissions, the adoption of energy-efficient equipment, and the implementation of smart monitoring technologies. The findings also indicate growing integration of carbon reduction objectives into business planning, supported by dedicated carbon strategy task forces, alignment with international climate commitments, and increasing investment in renewable energy systems. Collectively, these initiatives demonstrate that many firms are embedding sustainability into their core business strategies by improving operational efficiency, enhancing carbon management practices and supporting the transition towards a low-carbon economy. The finding is consistent with previous studies that highlight the importance of carbon-related disclosure and emissions reporting as an essential tool for managing climate-related risks (Choi et al, 2026). Additionally, there is evidence that climate risk disclosure can drive green innovation and promote investments in low-carbon technologies and sustainability initiatives, which are crucial for reducing emissions and achieving long-term decarbonisation (Peng et al, 2026). The growing focus on carbon management aligns perfectly with Malaysia's goal of achieving net-zero emissions and the implementation of national initiatives like the NETR. However, the moderate score highlights that there are plenty of opportunities for Malaysian energy firms to enhance their carbon reduction strategies and better align with global best practices.

The overall score for adaptation strategies is 44.64%, indicating a moderate level of preparedness to respond to the impact of climate change. The findings suggest that Malaysian energy firms have placed greater emphasis on operational measurs, particularly water efficiency initiatives, business continuity planning, and the protection

of water resources, whic recorded the highest levels of implementation. Firms also demonstrated moderate progress in monitoring and maintaining climate-resilient infrastructure and collaborating with government agencies on climate adaptation initiatives. However, more proactive and long-term adaptation measures remain less widely adopted. In particular, infrastructure planning against extreme weather events, the use of climate-resilient materials, early warning systems, rainwater harvesting, and green infrastructure development recorded relatively low levels of implementation. These findings suggest that, while firms are strengthening operational resilience, greater investment in strategic and long-term adaptation measures is required to enhance climate resilience across the sector. These findings are consistent with previous studies, which indicate that organisations are increasingly adopting climate adaptation and risk management practices to strengthen resilience against climate-related disruptions (Perera et al., 2026). Similarly, Malaysian energy firms have demonstrated greater progress in operational adaptation measures than in long-term adaptation planning. Furthermore, investment in climate-resilient infrastructure and adaptive management practices has been recognised as an important means of enhancing organisational resilience and adaptive capacity (Zhu et al., 2026). Nevertheless, the moderate Adaptation Strategies score suggests that adaptation efforts remain less developed than governance and disclosure-related activities. This observation reinforces previous studies showing that organisations, particularly in emerging economies, often prioritise climate mitigation over long-term adaptation because of financial, technological, and institutional constraints that limit investment in adaptive capacity.

Climate risk assessment recorded the lowest average score (36.88%), making it the least developed dimension of climate resilience among Malaysian energy firms. While most firms disclosed climate-related information in their annual and sustainability reports and acknowledged the importance of transition risks, the adoption of advanced analytical approaches remained limited. In particular, quantitative estimation of physical and transition risks, financial impact analysis, climate scenario analysis, and climate stress testing were reported by relatively few firms. Although some organisations have started integrating climate-related risks into enterprise risk management, systematic and forward-looking climate risk assessment has yet to become common practice across the sector. These results are consistent with earlier studies, which highlight that incorporating systematic climate risk assessment into corporate decision-making remains a major challenge despite growing awareness of climate-related risks (Kumarasiri et al, 2026). Likewise, Lyle et al (2026) found that many organisations continue to face difficulties in quantifying climate-related risks, even as their exposure to climate hazards increases. As reporting frameworks such as the TCFD, the ISSB, and Malaysia's NSRF place greater emphasis on scenario analysis, quantitative risk assessment, and resilience planning, the findings suggest that Malaysian energy firms are still developing these analytical capabilities. Although climate-related disclosure has improved considerably, further progress depends on strengthening quantitative risk assessment, scenario-based planning, and the integration of climate risk into strategic decision-making and enterprise risk management.

Figure 2 illustrates clear differences in performance across the four CCRASI dimensions, demonstrating that climate resilience practices among Malaysian energy firms are progressing at different rates. Governance and stakeholder engagement achieved the highest average score (59.55%), reflecting considerable progress in climate governance, board oversight, stakeholder collaboration, and organisational awareness. By contrast, climate risk assessment recorded the lowest average score (36.88%), largely because advanced practices such as quantitative risk assessment, climate scenario analysis, stress testing, and financial impact assessment remain relatively uncommon. The 22.67 percentage-point gap between these two dimensions highlights that firms have made substantially greater progress in strengthening governance and disclosure practices than in developing analytical capabilities for climate risk assessment. Carbon risk management (46.12%) and adaptation strategies (44.64%) recorded similar levels of implementation, suggesting that organisations are making steady progress in carbon mitigation, operational resilience, and business continuity planning. However, the relatively weaker performance in quantitative climate risk assessment and long-term adaptation measures indicates that forward-looking resilience planning has yet to become fully embedded within organisational practices. Collectively, these findings suggest that Malaysian energy firms are gradually integrating climate resilience into their governance and operational activities. Nevertheless, strengthening analytical risk assessment, scenario-based planning, and long-term adaptation strategies will be essential to achieving a more comprehensive and integrated approach to climate resilience management.

3.4 Implications

The findings indicate that climate resilience is increasingly vital to responsible business practices in the Malaysian energy sector. The relatively strong performance in governance and stakeholder engagement suggests that

many firms have successfully embedded climate governance, board oversight, stakeholder engagement, and organisational awareness into their business operations. Simultaneously, the moderate efficacy of carbon risk management and adaptation strategies suggests that companies are advancing in enhancing carbon reduction efforts, operational resilience, and business continuity planning. The CCRASI framework offers organisations a pragmatic instrument for assessing climate resilience, identifying capability gaps, and prioritising strategic actions to improve sustainability performance. Integrating climate resilience into corporate governance, enterprise risk management, and long-term strategic planning, enables organisations to strengthen adaptive capacity, enhance organisational resilience, and create sustainable long-term value.

However, the comparatively low performance of the climate risk assessment dimension highlights an important area requiring further attention. The findings suggest that Malaysian energy firms should strengthen quantitative climate risk assessment through greater adoption of financial impact analysis, climate scenario analysis, stress testing, and vulnerability assessments. Strengthening these forward-looking analytical capabilities would enable organisations to better anticipate both physical and transition risks, support more informed strategic and investment decisions, improve infrastructure resilience, enhance operational continuity, and reinforce long-term energy security.

At the policy level, greater institutional support is required to strengthen climate resilience assessment and reporting. Although Malaysia has introduced the National Sustainability Reporting Framework (NSRF), sector-specific guidance that incorporates climate risk assessment, adaptation measures, scenario analysis, and resilience indicators would improve the consistency, comparability, and decision-usefulness of climate-related disclosures. However, strengthening climate resilience requires more than improving disclosure requirements; it also depends on integrating climate considerations into organisational capabilities, governance structures, enterprise risk management, and business planning (Lyle et al, 2026). High-quality climate and ESG disclosures also play a critical role in reducing information asymmetry, strengthening stakeholder confidence, and supporting informed decision-making on climate-related risks and opportunities (Garrido-Merchán et al, 2026; Perera et al, 2026). Taken together, these measures can accelerate the transition towards a more competitive, sustainable, low-carbon, and climate-resilient energy sector while supporting Malaysia's long-term economic development and energy security goals.

4. Conclusion

This study assessed the climate resilience practices of Malaysian energy firms utilising the CCRASI from 2019 to 2024. The findings indicate a significant enhancement in climate resilience, as evidenced by the average CCRASI score increasing from 25.06% in 2019 to 68.86% in 2024, reflecting a growing organisational commitment to addressing climate-related risks. Among the four dimensions, governance and stakeholder engagement recorded the highest average score, indicating significant advancement in climate governance, board oversight, stakeholder collaboration, and organisational awareness. Carbon risk management and adaptation strategies exhibit moderate performance, indicating that firms are increasingly adopting carbon reduction initiatives, business continuity planning, and operational adaptation measures. In comparison, climate risk assessment was the least advanced dimension, mainly due to limited adoption of quantitative risk assessment, financial impact analysis, climate scenario analysis, and stress testing. The findings demonstrate that Malaysian energy firms have significantly advanced in governance and operational resilience. Nonetheless, additional focus is required on enhancing predictive analytical capabilities and formulating long-term climate adaptation strategies.

This study contributes to the responsible business and sustainability literature by demonstrating that corporate climate resilience can be understood as an organisational innovation capability that supports strategic decision-making, responsible business practices, and long-term organisational sustainability. The proposed CCRASI framework builds on existing approaches to climate resilience assessment by offering a comprehensive multidimensional tool for evaluating climate governance, carbon management, adaptation strategies, and climate risk assessment within a single framework. Beyond its academic contribution, the framework provides a practical benchmark for organisations, policymakers, and regulators to identify capability gaps, monitor progress, and strengthen climate resilience in support of Malaysia's transition towards a low-carbon economy.

Several limitations should be acknowledged. The study focuses solely on publicly listed Malaysian energy firms and utilises publicly accessible annual and sustainability reports, which may not comprehensively reflect actual organisational climate resilience practices. Secondly, the assessment relies on corporate disclosures and consequently does not assess the efficacy of the reported practices or their implementation in practice. Finally, the study encompasses solely the timeframe from 2019 to 2024. Future research may extend this work by

examining other industries, performing cross-national or cross-sector comparisons, exploring the relationship between climate resilience and organisational performance, and examining the impact of evolving sustainability reporting frameworks on corporate climate resilience over time.

Acknowledgements

This study received funding from the Ministry of Higher Education (MOHE), through the Fundamental Research Grant Scheme (FRGS) [Grant No. 20231014FRGS]. The authors express gratitude for financial support.

Ethics Declaration

Ethical approval was not required for this research because it solely examined publicly accessible corporate documents, such as annual reports and sustainability reports, without engaging human participants, conducting interviews, surveys, experiments, or accessing confidential information.

AI Declaration

Artificial intelligence (AI) tools such as ChatGPT, developed by OpenAI were employed to aid in language editing, enhance academic writing, improve clarity, and refine the manuscript's structure. The AI tool was not used to produce research findings, analyse data, interpret results, or derive the study's conclusions. The authors assume complete accountability for the content of this manuscript.

References

Choi, B., Lee, D. and Luo, L. (2026) "Carbon disclosure and common ownership", *Journal of Accounting, Auditing & Finance*, *41*(1), pp.220-253.

Garrido-Merchán, E.C., González-Barthe, C. and Vaca, M.C. (2023) "Fine-tuning ClimateBERT transformer with ClimaText for the disclosure analysis of climate-related financial risks", Neural *Computing and Applications*, *38*(1), p.12-29.

Intergovernmental Panel on Climate Change (IPCC) (2023) Climate Change 2023: Synthesis Report. Geneva: Intergovernmental Panel on Climate Change.

Intergovernmental Panel on Climate Change (IPCC) (2022) Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press.

Kumarasiri, J., Fisher, R. and Jubb, C. (2026) "Climate change-related regulatory disturbances and the accounting profession: longitudinal evidence from Australia", *Qualitative Research in Accounting & Management*, *23*(2), pp.229-260

Lyle, Z.J., VanBriesen, J.M. and Samaras, C. (2026) "Climate change risk index and municipal bond disclosures of United States drinking water utilities", *Communications Earth & Environment*, *7*(1), p.68-81.

Perera, K., Kuruppuarachchi, D., Suleman, M.T. and Kumarasinghe, S. (2026) "Climate change and idiosyncratic volatility: moderating role of ESG disclosure", *Applied Economics*, pp.1-19.

Peng, J., Dou, J. and Li, L. (2026) "How do climate risk disclosure peer effects propel corporate green innovation?", *Journal of Innovation & Knowledge*, *15*, p.101010.

Zhu, Y. and Wu, Y., (2026) "Climate risk and corporate cross-boundary digital innovation: An analysis based on the threshold effect of green digital finance", *Finance Research Letters*, *92*, p.109537.

Saha, A.K., Khan, I., Karim, M.R. and Alam, M.K. (2026) "Strategic climate change disclosures across temporal, directional, and thematic dimensions: Board dynamics and role of institutional ownership", *Journal of Environmental Management*, *398*, p.128437.