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THE ROLE OF GREEN INNOVATION IN CATALYZING CIRCULAR ECONOMY PRACTICES TO ENHANCE SUSTAINABILITY PERFORMANCE IN THE ELECTRICAL AND ELECTRONIC INDUSTRY

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Abstract:

As global concerns over environmental damage and resource scarcity, the Electric and Electronic (E&E) industry faces increasing pressure in enhancing its sustainability performance. Even though more focus is given to sustainability, limited research on the relationship between green innovation and circular economy practices in enhancing sustainability performance in this sector is being studied. Thus, this study aims to investigate the role of green innovation in driving sustainability performance and examine how circular economy practices affect and mediate this relationship within the E&E industry. The conceptual framework was developed based on two theories, which are the resource-based view (RBV) and natural-resource-based view (NRBV) theories. Both theories were used to explore the connection between green innovation, circular economy practices, and also sustainability outcomes. Using a narrative review approach, it aims at synthesizing and interpreting the data from the existing literature, specifically in E&E firms. The findings revealed that green innovation significantly contributes to improved environmental, economic, and social performance. Moreover, circular economy practices not only directly enhance sustainability performance but also help in mediating the effect of green innovation. This shows their function as a strategic enabler. This study uses a theory which enhances previous models by integrating RBV and NRBV. These theories explain how firms can build

Journal of Tourism, Hospitality and Environment Management
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sustainable competitive advantage through innovation and resource circularity. From a practical perspective, this study offers important guidance for industry stakeholders and policymakers who aimed at adopting integrated green and circular strategies to achieve long-term sustainability. Since the study focuses solely on the E&E sector in a specific regional context, future research should examine a wider range of industries and include other moderating variables to broaden and enhance the understanding of this subject matter.

Keywords:

Green Innovation, Circular Economy, Practices, Sustainability Performance, Electric and Electronic Industry

Introduction

In recent years, studies have been focused on sustainability issues in the Electric and Electronic (E&E) industry. The fact is E&E industry is always evolving, and it is one of the most dynamic and environmentally challenging industries in the world. Thus, in reality, sustainability problems with the new technology, short-lived use of products and more electronic waste or e-waste are issues (Gaur et al., 2024; Pan et al., 2022). A far better method or approach should be green innovation and CE with the new technology. Green innovation methods with eco technology and products are designed to preserve the environment, economic and social sustainability. Furthermore, CE practices with green innovation methods encourage more sustainability with product reuse, remanufacturing and recycling (Milhem et al., 2025; Jaiswal & Mukti, 2025).

Many studies support that CE practices significantly contribute to sustainability by: (1) increasing resource efficiency, (2) reducing waste intake, (3) lowering carbon emissions (Singh et al., 2022). In agreement with Kurnia et al. (2023) and von Kolpinski & Kratzer (2024), this way of doing business also contributes to: (1) generating jobs, (2) enhancing competitiveness, (3) promoting fair labour practices. In the context of the industry 4.0 framework, Mallik et al. 2024 observed improvements in terms of environmental and operational performance. A similar perspective is further supported by Tao et al., 2024 where both studies suggest that combined positive outcomes are connected to green innovation driven by digital technologies. However, the integration of CE and green innovation experience major challenges despite of their potential as reported by Jaiswal et al. (2023) and Pouyamanesh et al. (2023). It was believed that policy constraints, insufficient incentives, and weak imposed significant limitations to the practices. Therefore, thorough understanding on how green innovation could influence the CE implementation in the E&E industry must be prioritized.

Through this study, it addresses the uneven understanding of how green innovation acts as a driver of CE practices and their collective effect on sustainability performance in the E&E industry. Although both concepts have been studied separately, limited empirical and conceptual studies on each integration exists which explores their synergistic effects (Pan et al., 2022; Wong, 2012). Most previous studies focused on either green operations or mainly CE initiatives without considering the enabling role of innovation. Therefore, this paper proposes a conceptual framework to examine green innovation as a catalyst for CE practices,

Journal of Tourism, Hospitality and Environment Management
JTHEM
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Volume 10 Issue 41 (September 2025) PP. 346-359
DOI 10/35631/JTHEM.1041023
which influence the sustainability performance across the environmental, economic, and social aspects.

This study aims to lessen the gap by providing a comprehensive understanding of the interrelationship between the green innovation, CE practices, and also the sustainability outcomes. The proposed framework in this study offers theoretical and managerial insights which can assist firms, especially within the E&E sector, towards more integrated and sustainable business approach. This study also contributes to current discussions by highlighting enabling strategies such as digital transformation, stakeholder collaboration, and policy interventions (Gerasimova, 2024; Chinwego et al., 2025). On top of that, this paper also resides in its capacity to guide existing decisions and policymaking whereby it also aimed at enhancing green and circular transformation in resource-intensive industries.

This study is based on the theory of Resource-Based View (RBV) and also its extension, the New Resource-Based View (NRBV). These theories explain how the firms can leverage their unique capabilities such as green innovation, in order to gain its competitive advantage. (Lubis, 2022). The flow of the paper is structured as follows. First, Section 2 reviews the relevant literature and theoretical underpinnings. Next is Section 3, which presents the research design. Section 4 proposed the conceptual framework and methodology. Lastly, Section 5 summarizes the theoretical contributions, practical recommendations, and future research directions.

Literature Review

As a strategic response towards sustainability challenges in this E&E sector, the integration approach of green innovation and circular economy (CE) practices has captured the attention of the researchers. Scholars point up that green innovation comprising eco-friendly product design, cleaner production processes, and environmental technologies can act as a catalyst in reducing environmental impacts while enhancing firm competitiveness (Perotti et al., 2024). Meanwhile, CE practices could play its role in controlling the electronic waste (e-waste) and promote closed-loop supply chains. The CE practices include approach such as reuse, recycling, and remanufacturing. Besides that, the practices also are able to maintain the non-renewable resources (Pan et al.,2022; Gaur et al.,2024). Overall, these interrelated approaches could improve the environment, economic, and social aspects of sustainability (Milhem et al.,2025; Singh et al., 2022). However, despite the growing interest in these areas, there is a need for a comprehensive conceptual framework that captures their synergies and interconnections within the E&E context.

Recent research indicates that under Industry 4.0, with the adoption of digital transformation, it is preferable to use both green innovation and CE practices (Mallik, 2024; Tao et al., 2024). By means of digital transformation, it promotes sustainable design and recovery strategies by means of sophisticated technologies such as blockchain, IoT, and artificial intelligence, which offer real-time tracking of material flows, product life cycle assessments, and end-of-life management (Gerasimova, 2024). Not only that, digital tools empower firms to improve operational efficiency, increase transparency in the supply chain, and support collaborative business models that encourage circularity (Chinwego et al., 2025). However, Jaiswal and Mukti (2024) founded that there are significant barriers which prevent the CE adoption such lack of policy support, low consumer awareness and technological limitations. All these limitations hinder the application of CE practices as well as scaling up green innovation initiatives.

Journal of Tourism, Hospitality and Environment Management
JTHEM
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A conceptual framework on green innovation, circular economy (CE) practices and sustainability performance is introduced in this paper to investigate the relationships among these areas. By proposing this kind of framework, this study aims to address the aforementioned problems in the E&E industry. Based on the underlying theory, Pouyamanesh et al. (2023) noted that green innovation has a motivating effect on the emergence of CE practices and finally improves sustainability. This idea is in accordance with the recent studies which focus on environmental protection, economic strengthening and social well-being. Therefore, by modeling these relationships and considering the context of operation in E&E industry, this study acts as a guide for academicians, industry leaders and legislative managers who are aiming to develop strategies for sustainability performance.

Green Innovation

The study by Zailani et al. (2015) addressed how to improve production efficiency and become a green product. The result indicated that incorporating green innovations in the operational strategies will not only improve the company's competitive advantage but will also significantly reduce the consumption and emission of resources. It is even easier when green innovations are incorporated with the product and process innovations. According to Mallik et. al. (2024), the integration of Industry 4.0 technologies such as IoT, AI, and blockchain can boost green innovation within the companies. With the help of these tools, the products can be tracked and traced, and can be monitored at any instant of time. They have better control and visibility of the product life cycle. In addition to that, it enhances the transparency of the supply chain and becomes more efficient in the closed-loop management of electronic devices. Similar research has been done by Tao et al. (2024), which stated that when a company adopts digitally driven green innovations, it becomes easier for the business to achieve its sustainability targets.

Circular Economy

One of the ways to improve the sustainability performance in the E&E industry is through the application of CE practices, as it has become an important approach towards achieving sustainability through the reduction of e-waste, conservation of natural resources, and minimize environmental pollution. Some authors (Pan et al., 2022; Gaur et al., 2024) also added that if the company adopts CE practices such as reuse, remanufacturing, and materials recovery will gain several benefits such as reducing carbon gas emission, minimizing waste, and better use of resources. Research findings also revealed that adopting CE practices could strengthen economic resilience. For instance, if the company adopted CE strategies, it would experience cost savings from more efficient use of materials, create new job opportunities through innovative reuse and improve market competitiveness by providing sustainable products and services. In terms of social, CE practices can improve social welfare by providing a better working environment and encouraging the involvement of stakeholders as part of the circular economy (Quang et al., 2025; Singh et al., 2022).

Although CE practices have many benefits, Jaiswal and Mukti (2025) also discovered that CE practices have several challenges that may impact the implementation of CE practices. This result is also supported by Pouyamanesh et al. (2023), who also stated that the barriers such as policy gaps, inadequate infrastructure, and limited consumer awareness, could be the barrier that hinders the effective CE implementation. In addition to that, the findings also focused on developing more integrated and comprehensive policy frameworks along with stronger collaboration among several stakeholders, which are the governments, businesses, and consumers. By creating stronger lines of communication between these stakeholders, they will

Journal of Tourism, Hospitality and Environment Management
JTHEM
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be able to predict challenges, align their efforts, and find solutions that are sustainable in the long run.

Sustainability in the Electric and Electronic Industry

According to the study of sustainability in E&E industry done by Mathiyazhagan et al. (2021), the implementation of sustainable lean manufacturing will result in operational and economic performance. These practices focus on eliminating non-value-added operations and are driven by the environmental impact and the ongoing challenges associated with limited natural resources. Besides that, according to Benešová et al. (2024), although there is a financial constraint on the implementation, circular economy concept and global sustainability policies such as the EU Green Deal remain crucial in promoting sustainable practices. Consumer preferences increasingly favor sustainable electronic products, emphasizing features like energy efficiency and recyclability (Jose & Muhammed, 2024). Therefore, Ramprasad et al. (2022) suggest that paying attention to optimizing the extraction process and reducing the environmental impact, as there are a number of extraction processes that are in question for this research. This is important as the recovery of rare earth elements (REE) from the waste electrical and electronic equipment (WEEE) is vital for environmental conservation and sustainability purposes of the industry.

Sustainability performance in E&E sector is the result of a synergic relationship between green innovation and CE practices, as both these approaches are conducive to the three pillars of sustainability, which are: (1) environmental sustainability, (2) economic sustainability, and (3) social sustainability. As Milhem et al. (2025) stated, in pursuit of improved sustainability outcomes, green innovation can play a catalytic role in promoting CE practices. Similarly, Chinwego et al. (2025) found that the transition to circular and sustainable operations is only possible when companies operate with business models based on the principle of sufficiency, work together with stakeholders and are supported by appropriate policy incentives. Hence, by focusing on a systems-level approach instead of a concept focus, companies are in a better position to link their strategic capabilities to circular strategies to ensure long-term sustainability and competitive viability in E&E industry. In other words, being sustainable will leave a legacy for our future children, meet market expectations, and save the environment.

The Adoption of Resource-Based View (RBV) and Natural Resource-Based View (NRBV) Theory

Following the results of Arda et al. (2023), RBV theory tries to apply green practices at every stage of the supply chain in order to be sustainable and gain a competitive advantage. Similarly, following the results of Kero and Bogale (2023), by using RBV theory, it tries to apply green practices at every stage of the supply chain in order to achieve more sustainable performance and a better position in the market. These authors said that companies can achieve environmental sustainability by using their resources that can be named as VRIN (Valuable, Rare, Inimitable and Non-Substitutable). These strategic assets and its capabilities include knowledge-based resources, human capital, physical infrastructure, technology and digital tools and organizational capabilities. By using its own strengths, the company can create its own sustainability ways which is to support the environment and a competitive advantage in the E&E industry. Following this idea, Jayasinghe et al. (2021) also further strengthened the importance of green technologies, skilled personnel and an innovative approach. While in another study by Lubis (2022), it is stressed that it is possible to create sustainable value and

Journal of Tourism, Hospitality and Environment Management
JTHEM
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competitive benefits in E&E industry by identifying and developing internal strengths and capabilities with RBV.

Jayasinghe et al. (2021) highlighted that the NRBV theory has been developed as an extension of the RBV theory. The NRBV theory is focus more on the need to meet the modern sustainability challenges. Under the RBV theory, companies competitive advantage rooted in its internal resources, especially those that are valuable, rare, inimitable and non-substitutable (VRIN). However, unlike earlier studies, Khan et al. (2022) reviewed that the NRBV theory is the extension of this perspective by emphasizing on the strategic importance of environmental management, including green innovation, waste reduction and sustainable product design. He reported that businesses in the E&E industry that adopt these green technologies are better equipped to meet government standards, respond to consumer demand for eco-friendly products, and overcome the lack of resources, which all leads to better sustainability performance

In addition, this paper provides an understanding on how green innovation affects a company's performance through NRBV theory. Thus, Lestari et al. (2024) provide a valuable insight by demonstrating that green innovation mediates the relationship between the presence of female directors and firm value. These results support the NBV theory that has claimed that environmentally friendly resources can increase firm value. This means that the CE practices focusing on eco-design, remanufacturing, and recycling practiced with environmentally friendly resources, which are the initiatives taking into account the environment in the process, can contribute to the environment as well as operations. These practices are supported by organizational resources such as R&D, digital technology and a knowledge sharing system (Ali et al., 2024). Moreover, the combination approach of CE practices with the RBV and NRBV frameworks is supported by the idea of using internal resources for facilitating closed material loops, reducing environmental impact and creating long-term value (Singh et al., 2023). Previous studies have investigated the digital transformation and its effect on supporting green innovation. The use of digital technologies can enhance green innovation by providing a firm with the ability to collect, process, and act on sustainability information (Zhang et al., 2025). When companies in the E&E sector use their internal resources in a strategic way for CE and green innovation practices, the companies are better positioned to achieve sustainable competitive advantage and improved sustainability outcomes as shown in the theoretical framework discussed.

Besides, Singh et al. (2023) argued that when companies strategically align their internal resources with CE practices by integrating CE practices with the RBV and NRBV frameworks, the company will be able to achieve closed-loop operation, reduce environmental impact and sustain long-term value creation. Ali et al. (2024) further added that CE strategies can contribute towards both the environment and operation. Companies' internal resources, such as R&D, digital technology and a knowledge sharing system, support the implementation practices such as eco-design, remanufacturing and recycling. Zhang et al.'s (2025) recent studies show that digital transformation encourages green innovation initiatives. These initiatives can strengthen green innovations' initiatives by providing a firm the ability to gather, analyse and act on sustainability data (Zhang et al., 2025). Previous studies (Raghavendra & Sheethal, 2024) have been concerned with how E&E firms can strategically align their internal resources with green innovation and CE practices to improve business and enhance operational effectiveness, optimize resource inputs and minimize waste.

Journal of Tourism, Hospitality and Environment Management
JTHEM
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In summary, both RBV and NRBV theories can be used as a strong theoretical background to encourage businesses in E&E industry to adopt green innovation and CE practices. As Shaharudin et al. (2023) pointed out that both approaches rely heavily on the company's own internal resources and capabilities. Although integrating digital technologies into circular economy (CE) practices faces some challenges, there are benefits gained from such integration. The benefits, such as better use of resources and enhanced operational efficiency, can assist companies in achieving sustainable competitive advantage and boost the sustainability performance in this industry.

Research Design

The approach used in this paper is secondary data collection method through a narrative literature review. The aim of narrative literature review is to synthesize the primary and secondary data, including research, articles, case studies and industry reports and also conceptual relationships (Snyder, 2019). It was intended to examine how green innovation promotes CE practices could improve sustainability performance in E&E industry. According to Torraco (2005) and Webster and Watson (2002), narrative literature review also provides a structured but flexible approach which suitable for new and emerging topics that involve multiple perspectives.

Conducting a Narrative Review

The articles for the literature review were extracted through an online database search. Scopus was used as the main reference for this study. It focused on articles which are English language from 2010 to 2025. This period was chosen because it encompasses the fast changes of Industry 4.0, which is driven by emerging technologies and a policy framework which supports CE practices. Titles and abstracts were evaluated for relevance to the study's core constructs (green innovation, CE practices, sustainability), followed by full-text appraisal to confirm alignment with the research objective. Duplicate records were removed, and backwards citation tracking was employed to capture essential works not retrieved in the initial query. Throughout this process, inclusion criteria prioritized empirical studies, literature reviews, and theoretical papers that explicitly addressed the interplay among green innovation, CE practices, and sustainability in the electric and electronic sector.

Journal of Tourism, Hospitality and Environment Management
JTHEM
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Data Collection

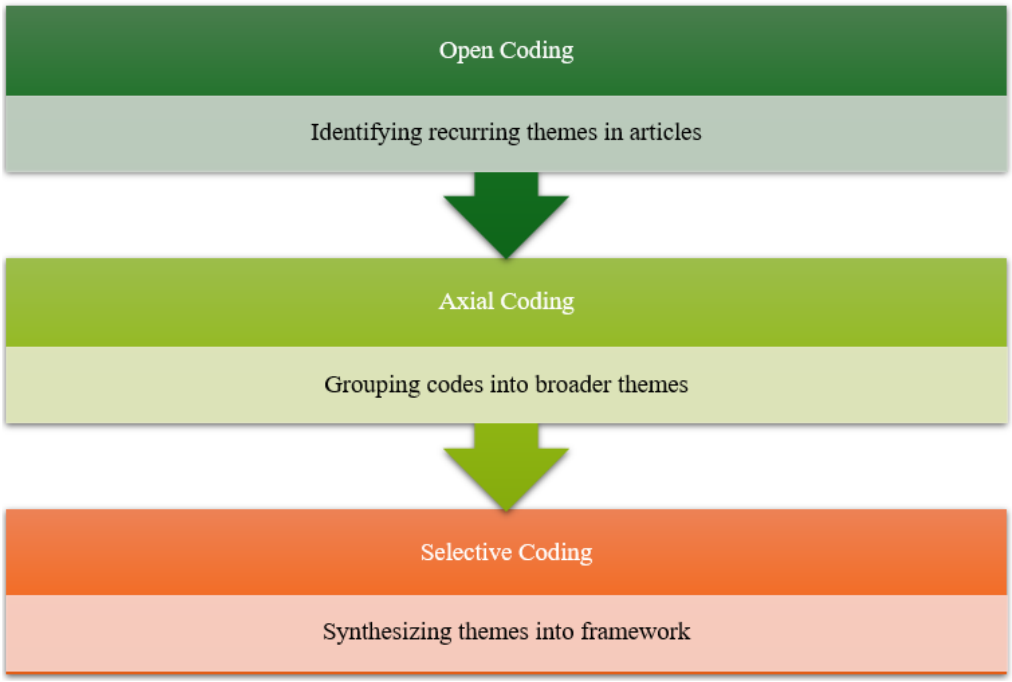

Figure 1: Data Analysis Process Funnel

For this study, data collection was conducted using the final search string which combined key terms with Boolean operators such as "green innovation" OR "green innovation strategy" OR "competitive advantage" AND "circular economy" OR "sustainable development", AND "sustainability" OR "sustainability in green practices".

According to Figure 1, initially open coding was used to identify recurring themes such as resource efficiency, digital enablers and policy drivers. After the open coding process, the initial codes were organized under axial coding into more general categories such as “Innovation Drivers”, “Circular Practices”, and “Sustainability Outcomes”. The next step involved using selective coding. Through selective coding, these categories were combined into a conceptual framework that illustrates how green innovation drives circular economy (CE) practices that supports overall sustainability performance (Torraco, 2005).

Development of the Theoretical Framework

The development of the theoretical framework for this study was based on two theories, namely the Resource-Based View (RBV) and the Natural-Resource-Based View (NRBV). Previous studies have also shown that the two theories provided a holistic view on how company can utilize their internal resources to achieve sustainable performance through green innovation and CE practices. The previous findings also suggested that applying these two theories in the E&E industry will help the company to improve the intensive use of resources and also the product life cycle. In addition, previous research on these two theories has also shown the strategic importance of incorporating environmental factors into a company's core business. Therefore, the previous studies have also shown that applying the RBV theory would help the company to sustain competitive advantage by leveraging on the role of unique firm-specific resources and firm capabilities related to the theory (Barney, 1991). The previous study by Hart (1995) also stated that the concept of Natural Resource-Based View (NRBV) is the extension of the Resource-Based View (RBV) idea. The NRBV theory emphasizes on the benefits of

Journal of Tourism, Hospitality and Environment Management
JTHEM
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DOI 10/35631/JTHEM.1041023

environmental competencies such as pollution control, product stewardship and sustainable development. When a company adopts green innovation and CE as part of its strategic capability, the company is better positioned to address environmental and economic goals. These two aspects would help the company to gain a competitive advantage as well as respond to sustainability pressure.

To illustrate the relationship between green innovation and the mediating role of CE practices, this study proposed a conceptual framework to demonstrate how both variables could influence the sustainability performance. Green innovation, which consists of eco-design, green manufacturing and eco-friendly product development, is seen as a driving force for CE strategies such as recycling, remanufacturing and resource recovery (Wong, 2012; Tao et al., 2024). Due to the CE strategies, in turn, it enhances the environmental, economic and social performance. The environmental performance can be seen through waste reduction and emission control. While economic performance in terms of cost savings and competitiveness, and lastly through social performance such as employee well-being and community impact (Singh et al., 2022; Milhem et al., 2025). This framework is further reinforced through thematic integration of empirical studies retrieved from the Scopus database, which demonstrate how digital enablers like blockchain and IoT support the operationalization of CE initiatives in the E&E sector (Gerasimova, 2024; Mallik, 2024). Hence, the framework not only captures causal relationships but also elucidates mechanisms of interaction between innovation, circularity, and performance outcomes.

Given the preceding discussion, Figure 1 illustrates the propose theory of the study.

Figure 2: Proposed Theoretical Framework

This framework provides a roadmap for firms and policymakers to align sustainability strategies with operational capabilities. For firms, the integration of green innovation and CE practices facilitates regulatory compliance, brand differentiation, and long-term resource security which are the key drivers of sustainable competitiveness (Chen, 2014; Quang et al., 2025). For policymakers, the framework emphasises the importance of supporting industry-wide green transformations through incentives, infrastructure, and collaborative platforms. Ultimately, this study contributes to theory by extending NRBV through a circular economy perspective and contributes to practical insights into how E&E firms can transition from conventional to sustainable business models. The framework serves as a foundation for future empirical research exploring dynamic capabilities, institutional constraints, and stakeholder engagement in green transformations.

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Proposition Development

Green Innovation Influences Sustainability in the Electric and Electronic Industry

Green innovation can act as a strategic enabler for sustainable performance in the electric and electronic (E&E) sector. The industry itself has high environmental effect and resource intensity which by implementing the green innovation could improve companies' ability to maximise environmental, economic, and social results. Green innovation emphasizes on applying approach such as eco-friendly technologies, green manufacturing techniques, and circular product design. Studies have shown that the strategy to link between green innovation with circular economy practices such as recycling, reuse, and resource recovery could improve company performance. This strategy will improve result such as lowering the production costs, reducing waste and emissions, and enhancing stakeholder involvement (Pinheiro et al., 2022; Sun et al., 2025). Smarter product designs and operational efficiencies in line with circular ideas are made possible by green innovation which is supported by Industry 4.0 technologies such as artificial intelligence and big data analytics (Pereira et al., 2024). Past studies have also looked into the fact that stakeholder pressure and sustainable supply chain collaboration would be able to promote the use of green policies by motivating companies to achieve more general sustainability goals (Khan et al., 2024; Danko et al., 2023). Furthermore, Bashynska et al. (2024) also found that electrical multinational companies that practiced circular economy are more successful in using green innovation to ensure secure access to resources, sharing of information and expanding CE practices. Therefore, proceeds to the following proposition:

Proposition 1: *Green innovation has a positive impact on the sustainability performance of firms in the electrical and electronic industry.*

Circular Economy Practices Mediate the Relationship Between Green Innovation and Sustainability Performance in the Electric and Electronic Industry

The mediating function of CE practices is strengthening the link between sustainability performance and green innovation in the E&E sector. Businesses adopt more circular strategies as a result of green innovation, which is enhanced by eco-friendly technologies, sustainable product designs, and pollution-reducing procedures. Nevertheless, the adoption of CE practices that include reuse, remanufacturing, and recycling transforms green innovations into practices, increasing their impact and effectiveness on the overall performance of the social, economic and environment (Pinheiro et al., 2022; Khan et al., 2024). Effective green knowledge sharing and a creative climate allows businesses to adopt and scale CE practices more effectively, while the use of cutting-edge technology from a green innovation perspective improves the circular product design (Sun et al., 2025).

In such a way, CE practices serve as a bridge that translates innovative capabilities into tangible sustainability gains by optimizing resource efficiency, reducing waste, and aligning with stakeholder expectations (Danko et al., 2023; Bashynska et al., 2024). Therefore, circular economy practices not only complement but also mediate the link between green innovation and sustainability performance by ensuring that innovations are integrated into the firm’s operational and strategic framework. Thus, this led to the following proposition:

Proposition 2: *Circular economy practices mediate the relationship between green innovation and sustainability performance in the electric and electronic industry.*

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Conclusion

This study emphasises the importance of green innovation and circular economy practices in enhancing sustainability performance within the electric and electronic industry. It concludes that green innovation positively influences sustainability outcomes and that circular economy practices not only have a direct impact on sustainability performance but also mediate the relationship between green innovation and sustainability. Theoretically, the study advances understanding by integrating the resource-based view and natural-resource-based view to explain how firms leverage internal capabilities and environmental strategies to achieve sustainability goals. Practically, it provides industry leaders and policymakers with strategic insights into implementing circular and green practices to drive environmental, economic, and social performance. However, the study is limited by its industry focus, which may restrict generalizability across other sectors and regions. Future research could expand this framework by exploring cross-industry comparisons, long-term impacts, or the role of external moderators such as regulatory frameworks and technological readiness

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