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ROLE OF GREEN TECHNOLOGY INNOVATION TO PROMOTE SUSTAINABILITY PERFORMANCE IN MALAYSIAN MANUFACTURING SOLAR PV INDUSTRY: A CONCEPTUAL FRAMEWORK

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ABSTRACT

Manufacturing organisations should embrace green technology innovation that strengthens their sustainable performance in a continuous dynamic market to promote coordinated natural environmental, social, and economic development. Pertaining to this objective, several studies have been performed to enhance the adoption of green technology innovation and sustainability performance. Nonetheless, the existing literature is insufficient to clearly indicate whether green technology innovation enhances sustainability performance in the Malaysian Solar Photovoltaic (PV) industry. Therefore, this study aims to construct a conceptual framework by documenting the relationship between green technology innovation and sustainability performance in the Malaysian PV industry. To empirically validate this relationship, this study proposed the collection of data through primary sources from the Malaysian manufacturing solar PV industry, incorporating a 5-point Likert scale. Regarding the data analysis, Partial Least Square-Structural Equation Modelling (PLS-SEM) is proposed to investigate relationships between constructs and latent variables. With theoretical support, the proposed results indicate that green technology innovation enhances sustainability performance, specifically in Malaysian manufacturing solar PV organisations. In practice, this paper helps policymakers to design comprehensive policies and systematic guidelines for strengthening sustainability performance through the adoption of green technology innovation, specifically in the solar PV manufacturing industry. Scholarly, it will also enrich the existing body of knowledge on green technology innovation and its impact on sustainability performance in the Malaysian manufacturing solar PV industry.

Keywords: *Green technology innovation, sustainability performance, solar PV industry, manufacturing organisations*

INTRODUCTION

Manufacturing organisations have substantially contributed to consolidating the economies of many nations. Due to rapid industrial development, manufacturing organisations have been experiencing cumulative environmental challenges. The sensitive operations of manufacturing organisations impose severe negative impacts on the natural environment and create conflicts between stakeholders and organisations. The solar PV industry cannot be excluded from organisations experiencing the negative impact of business operations by using harmful toxins or pollutants (Kumar et al., 2022). Utilising toxic materials for producing solar PV products, such as solar panels and solar air conditioners, require significant energy, potentially contributing to global warming and climate change.

Without proper safety measures and emission control, manufacturing processes can create health risks for workers and surrounding communities. Manufacturing processes can often contribute to social inequality, as the processes are often concentrated in poorer areas where workers may not be adequately protected from hazardous working conditions and may receive low wages. Additionally,

unsustainable manufacturing processes also lead to the destruction of natural habitats, resulting in a loss of biodiversity (Kashif & Lai, 2019). Using large quantities of natural resources such as water, minerals, and energy contribute to environmental and social issues. These circumstances have made manufacturing organisations care for and contribute more to sustainability to ensure the protection of the natural environment and nearby communities. Nowadays, stakeholders are much aware of these environmental and social challenges and imposing pressure on organisations to optimise their sustainability performance. To enhance sustainability performance, organisations must achieve a balance in economic, social, and environmental processes and be successful in their attempts regarding all these three dimensions (Shah et al., 2022).

Sustainability performance enables organisations to perform better than their competitors for a short and long period of time. From a financial perspective, which is an organisation's main objective, sustainability performance significantly impacts organisational success through accounting indicators such as profitability, investment turnover, and sales (Mukhtar et al., 2023b). While from a non-financial perspective, sustainability performance raises the level of customer satisfaction and societal well-being. However, due to the complexity of these three dimensions of sustainability performance and their relationship to each other, it is not easy to sustain balance and successfully enhance environmental, economic, and social performance. To achieve greater sustainability by maintaining the balance between all three dimensions, various approaches such as modern technology, financial resources, intellectual capital orientation, and knowledge management were utilised, as evident from existing literature (Al-Nimer et al., 2021). Besides, from the literature, it was found that green technology innovation is the most important aspect that can impact the sustainability performance of manufacturing organisations.

Green technology innovation encompasses the ability of an organisation to apply creative ideas in developing environmentally friendly products and processes to gain competitiveness (Shahzad et al., 2020). According to Xu et al. (2022), green technology innovation enhances communities' well-being and resolves potential conflicts between stakeholders and organisations. Thus, it is indispensable to study green technology innovation to enhance the sustainability performance of manufacturing organisations. Scholarly, various studies have been performed around the concepts of green technology innovation and environmental, social, and economic performance discretely. But the existing literature is evidence of scarce attention that has been granted in providing any clear and obvious impact of green technology innovation on sustainability performance, counting all three environmental, social, and economic performances in the Malaysian manufacturing solar (PV) industry. Consequently, based on the resource-based view (RBV) theory, this study conceptualizes a framework to explore the effect of green technology innovation on sustainability performance by documenting environmental, social, and economic performance in manufacturing solar PV organisations.

The remainder of the document is constructed as follows: the next section delivers the literature review. Section three offers the theoretical foundations for the relationship between green technology innovation and sustainability performance. Next, this study proposes a conceptual framework, followed by a description of the research methodology. Then, the next section provides a conclusion and implications of this study. Finally, the last section of this study delivers future recommendations.

LITERATURE REVIEW

Green technology innovation and sustainability performance are gaining increasing attention in both academic research and industrial practice. Numerous studies have contributed to the body of knowledge by considering different aspects. This study focuses on two associated literature streams: green technology innovation and sustainability performance. The main debate is whether organisations may enhance their sustainability performance by comprehensively implementing green technology innovation. The included variables are explained in subsequent sections.

Green Technology Innovation

Theorists have emphasized implementing green technology innovation to accomplish sustainable development and competitive advantage. Green technology introduces advanced foreign technology with low market risk, low capital requirement, and a short return cycle. Scholars and researchers have utilised green technology innovation to gain significant strategic outcomes. For instance, Pekovic & Bouziri (2021)

vindicated that green technology innovation helps achieve a competitive advantage and enhances societies' environmental sustainability and social well-being. Ashrafi et al. (2019) implied that green technology innovation enriches the organisational capacity of innovation to address the pertinent concerns of organisations and stakeholders. Moreover, Singh et al. (2022) inferred that green technology innovation enables organisations to discover technologies that contribute to energy conservation, emission reduction, and the overall development of sustainable communities. Likewise, Arunachalam et al. (2020) suggested that green technology innovations might enhance the firm's image and reputation, making it more attractive to investors for capital financing.

Furthermore, Fang (2023) contended that the advancements in green technology innovation optimize the usage of renewable energy resources and reduce the emissions of pollutants. In addition, Wicki and Hansen (2019) asserted that green technology innovation accentuates environmental protection, which can effectively reinforce resource and energy utilization efficiency compared to general technological innovation. With such significance, it is imperative to integrate green technology innovation to enhance the sustainability performance of the manufacturing industry. Following the empirical study of (Wang et al., 2022), this study segmented green technology innovation into green product innovation, green process innovation, and end-of-line management innovation, which are explained in the following sections.

Green Product Innovation

Green product innovation refers to creating eco-friendly products using fewer, non-toxic, and biodegradable resources (Andersén, 2021). Through sustainable product innovation, the durability and recyclability of products can be enhanced, allowing organisations to choose environmentally healthier raw materials in product formation. According to Shad et al. (2019), green product innovation offers economic benefits for businesses by decreasing leading expenses and initiating cost-effective alternatives. Meanwhile, Chiou et al. (2011) explained that sustainable product innovation prevents organisations from dealing with environmental disputes and legal penalties. Furthermore, green product innovation also increases customer loyalty as customers become more aware of the environmental impact of their purchases.

Green Process Innovation

Sustainable process innovation improves the practice of production and recycling processes. Exclusively, the operational performance of production processes can only be enhanced through sustainable process innovation, which transforms raw materials into a final functional product (Iranmanesh et al., 2017). In the meantime, sustainable process innovation heightens the designing and implementation of production processes that are more suitable and sustainable for the natural environment. By incorporating green process innovation, organisations stand out from their competitors by establishing a brand reputation for being environmentally responsible and sustainable (Shah et al., 2021). By adopting green process innovation, organisations demonstrate competitive commitment to the environment, which helps them to become ecologically responsible and reliable.

End-of-line Management Innovation

End-of-line management innovation refers to integrating technological innovations that improve the efficiency of three-waste treatments, including wastewater, waste gas, and waste residue (Ren et al., 2022). The integration of technologies contributes to the development of sustainable products by reducing input materials and energy requirements and extending the lifecycle of products (Asadi et al., 2020). Effective treatment technologies are needed at the end of the production process to ensure compliance with pollutant discharge standards. In this regard, green product innovation and process innovation leverage existing and emerging technologies to assist the origination of a more sustainable future.

In a nutshell, the better implementation of green technology innovation with green product innovation, process innovation, and end-of-line management innovation is essential in establishing better organisations' green and economic picture in emerging markets. Consequently, green technology innovation is the appropriate and comprehensive approach by which organisations reduce overall unfavourable outcomes and improve sustainable performance.

Sustainability Performance

The significance of sustainability has been emphasized in all business sectors. The industrial paradigm focuses more on economic parameters than environmental protection (Shad et al., 2019). Specifically, the concept of

sustainability within manufacturing organisations implies a focus on serving the needs of the organisation's direct and indirect stakeholders. Implementing sustainability to stakeholders includes three processes: accounting, assessment, and reporting. The accounting process focuses on what data should be gathered and for what purpose. The assessment aspect offers significance to the collected qualitative and quantitative data through the analytical integration methods. Once it has been accounted for and assessed, the entire sustainability performance can subsequently be reported as a strategic tool for corporate management and communication. Regarding the significance of sustainability, Kashif et al., (2018) stated that shareholders are most likely to reward organisations in terms of investment with superior sustainability performance. Bose et al. (2022) argued that the sustainability performance of organisations tends to have better access to valuable resources, higher employee retention, create unanticipated opportunities, and gain social legitimacy. Kılıç et al. (2022) illustrated that sustainability performance improves organisational financial performance by increasing the return on assets (ROA) and return on equity (ROE), and organisational reputation. Moreover, Ilyas et al. (2020) implicit that sustainability performance nurtures behavioural integration within boards and operational executives.

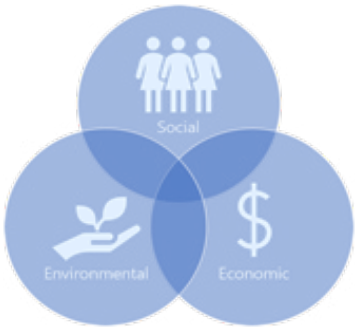


Figure 1 Triple Bottom Line Concept of Sustainability Performance Proposed by Elkington (1994) (Source: Social Accountability International)

In the existing body of knowledge, sustainability includes the Three Bottom Line (TBL) concept, including three critical dimensions: Economic, Environmental, and social. As a result, an organisation's sustainability performance contributes to economic well-being, environmental protection, and social stability. In addition, the TBL framework evaluates the organisation's sustainability performance in a broader context to create greater sustainable development. The pictorial formation of the Triple Bottom Line concept is shown in Figure 1.

Triple Bottom Line Concept of Sustainability Performance

Environmental sustainability performance is regarded as a fundamental dimension of TBL's concept of sustainability performance, and it is defined as how effectively an organisation minimizes its environmental impact (Li et al., 2020). Organisations must assess this performance by determining the impact of their operations on the natural environment as well as the effectiveness of their efforts to reduce that impact. Organisations in any community must address environmental issues because unsustainable actions lead to the depletion and degradation of natural resources (Mukhtar et al., 2023a). The second pillar of sustainability performance is economic sustainability performance organisations have always placed a high value on priorities (Sarkar et al., 2022). Economic sustainability performance aims to enhance the market value of organisations (Shad et al., 2022). Economic sustainability encompasses financial benefits and indicates an organisation's long-term financial viability and profitability (Jan et al., 2019; Lai et al., 2018). Literature indicates that economic sustainability performance is measured in terms of organisational and productivity performance, ROA, ROE, and market value (MV). Investors can use these key performance indicators to comprehend or assess associated risks and return, as well as earning quality, associated with their investments (Kashif & Lai, 2019).

The final pillar of Triple Bottom Line (TLP) is social sustainability, which incorporates various social aspects such as equality, employees development, health & safety, equal opportunities for advancement, and contribution toward community welfare activities (Lai et al., 2017; Torkayesh et al., 2021). Organisations should focus on economic and environmental perspectives and give more attention to social performance (Hamad et al., 2023). For manufacturing organisations, the products and production operations should not be harmful to society and customers. The achievement of sustainable development goals (SDGs) such as SDG 3 (Good health and well-being), SDG 4 (quality education), SDG 5 (gender equality), and SDG 10 (reduce inequalities) enforces the organisations to enhance their social performance. Social sustainability is vital for addressing

relevant social issues and maximizing social satisfaction (Santos & Moreira, 2022). Corporate performance regarding social sustainability is linked to a business structure that meets stakeholders' social expectations and minimises long-term negative environmental impact (Sugandha et al., 2022).

Green Technology Innovation and Sustainability Performance

Sustainability performance is getting much more important as the organisations' sustainable-oriented activities. Therefore, green technology innovation could be very important for the sustainability performance of organisations. With the help of empirical evidence, it has been found that the literature is concentrated on the impact of green technology innovation on organisations' environmental and financial performance. For instance, using the panel data from 2011 to 2017 in China, Cao et al. (2021) examined that green technology innovation as a transmission path enhances energy-environmental performance by effectively implementing digital finance in organisations. Zailani et al. (2014) performed a study in the context of the Malaysian transportation industry where the relationship between green technology innovation and environmental outcomes was investigated. Based on the survey results, it was found that green technology innovation has a significant positive relationship between green technology innovation and environmental performance.

Using the 283 Indian manufacturers as a sample population, Sahoo et al. (2022) described green technology innovation as a catalyst to improve environmental performance. Moreover, Awawdeh et al. (2022) examined the effect of green technology innovation on production, continuous improvement processes, stakeholder satisfaction, as well as the development of training models. As a result, the overall performance of the organisation is improved. In the same vein, Xu et al. (2022) concluded that green technology innovations contribute to a reduction in production, operating, manufacturing, and processing costs, thereby increasing revenues and the overall economic performance of organisations. In addition, Qing et al. (2022) found a significant positive impact of green technology innovation in terms of product innovation and process innovation on short-term and long-term financial performance.

The extensive literature on green technology innovation concludes that most research has merely focused on the economic and environmental impact of green technology innovation. However, no clear link has been established between green technology innovation and sustainability performance, including all three dimensions such as environmental, economic, and social performance. Hence, conducting a research study focusing on green technology innovation and sustainability performance would be of significant interest. Therefore, this study conceptualizes a framework to explore whether green technology innovation improves sustainability performance, including economic, environmental, and social performance in the Malaysian manufacturing solar PV industry.

THEORETICAL FRAMEWORK

This study proposes that the Resource-Based View (RBV) theory underpins the relationship between green technology innovation and sustainability performance. The RBV theory proposed by Barney in 1991 helps to optimize organisational resources. The RBV theory sheds light on the value of tangible and intangible resources for superior performance (Barney et al., 2011). This theory has rarely been touched on in the context of green technology innovation and sustainability performance (Al-Nimer et al., 2021). The RBV theory has been tested in different domains but has not yet been discussed in the context of green technology innovation and organisational performance, particularly non-financial performance. In the present study, we examined whether the intangible resources, namely green technology innovation, contributed to organisational performance or not. According to the RBV theory, the ability of resources in green technology innovation may contribute positively to organisations' overall outcomes (Bailey, 2022). Therefore, organisations will use their best resources in the form of green technology innovation to enhance sustainability performance by achieving the best possible business outcomes.

CONCEPTUAL FRAMEWORK AND HYPOTHESES DEVELOPMENT

This research work proposes a conceptual framework that consolidates the impact of green technology innovation on sustainability performance in manufacturing solar PV organisations. The proposed

conceptual framework comprises two groups of variables: green technology innovation as an independent variable, whereas the dependent variable is sustainability innovation which will be proxied by environmental, social, and economic performance. It is principally theorized that green technology could positively affect environmental, social, and economic sustainability performance. Details about the conceptual framework are shown in Figure 2.

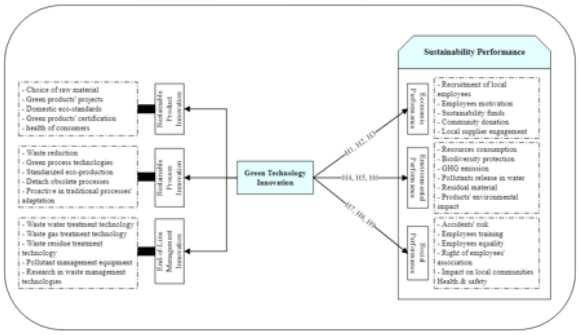


Figure 2 Conceptual Framework (Authors' Own Creation)

Based on the conceptual framework, this research work developed the following proposed hypotheses. The development of the proposed hypotheses is predicted based on the notion that effective green technology, which will be proxied by green product innovation, sustainable process innovation, and line management innovation, is beneficial in enhancing economic, environmental, and social sustainability performance. The following proposed hypotheses will test the verification of these associations.

1. **H1**: Green product innovation will have a positive impact on environmental performance.

2. **H2**: Green product innovation will have a positive impact on social performance.

3. **H3**: Green product innovation will have a positive impact on economic performance.

4. **H4**: Green process innovation will have a positive impact on environmental performance.

5. **H5**: Green process innovation will have a positive impact on social performance.

6. **H6**: Green process innovation will have a positive impact on economic performance.

7. **H7**: End of Line-management innovation will have a positive impact on environmental performance.

8. **H8**: End of Line-management innovation will have a positive impact on social performance.

9. **H9**: End of Line-management innovation will have a positive impact on economic performance.

DESCRIPTION OF METHODOLOGY

Sample Population and Instrument Development

The Malaysian manufacturing solar PV organisations have been included in this study as the target population. The proposed data collection is intended to be conducted among all 30 Malaysian solar PV manufacturing organisations listed in the Malaysian Photovoltaic Industry Association (MPIA). Besides, a census method is proposed to sample the target population of this research. The census method includes all target population elements in the sample frame. According to (Sekaran and Bougie (2013), the census method is feasible and realistic if the target population (Industries and individuals) is relatively small. Hence, the current study suggests investigating each unit of the target population using the census method, leading to high accuracy in concluding. This study is proposed to focus on primary data, which will be collected through a questionnaire incorporating a Five-point Likert scale from Malaysian solar PV manufacturing organisations. Senior and middle-level professionals who are responsible for green technology innovation and sustainability performance are ideal respondents for this study. To ensure the questionnaire's validity, content validity will be conducted to confirm whether the respondents easily understand and answer the survey questions.

Measurement of Variables and Data Analysis

Regarding the measurement, green technology innovation will be measured through green product innovation, green process innovation, and end-of-line management innovation. The questionnaire items for all three dimensions will be adapted from the study of (Wang et al., 2022). On the other hand, to measure the sustainability performance, including economic, social, and environmental performance, this study suggested the adaptation of scale from the study of (Chege & Wang, 2020). The adaptation of scale

with no of items and sources is displayed in Table 1. It is recommended that questionnaire items should be adapted from established studies to ensure their reliability and validity. Before being used in the analysis, the collected data must be carefully checked. PLS-SEM will be employed to scrutinize the impact of green technology innovation on sustainability performance. Utilising the PLS-SEM, measurement and structural model analysis will be performed (Hussain, Abid, et al., 2023). The measurement model will check internal consistency reliability, convergent validity, and discriminant validity. On the other hand, an analysis of the structural model will be performed to analyse the Coefficient of determination (R2), effect size (f2), and significance level (Hair et al., 2019; Hussain, Hooi Ting et al., 2023).

Table 1 Variable Measurement (Authors' Own Creation)

Variable	No of Items	Sources
Green Technology Innovation		
Green Product Innovation	5	
Green Process Innovation	5	(Wang et al., 2022)
End-of-line Management Innovation	5	
Variable	**No of Items**	**Sources**
Sustainability Performance		
Economic Practices	5	
Environmental Practices	6	(Chege & Wang, 2020)
Social Practices	6	

CONCLUSIONS AND IMPLICATIONS OF THIS STUDY

This study aims to conceptualize a framework to explore whether green technology innovation impacts sustainability performance, including economic, environmental, and social performance in Malaysian manufacturing solar PV organisations. The literature does not clearly indicate the relationship between green technology innovation and sustainability performance, including the Triple Bottom Line concept. Thus, based on the underpinning RBV theory, this study conceptualized the relationship between green technology innovation and sustainability performance. This research work is hypothesized that the comprehensive implementation of green technology innovation will positively impact sustainability performance.

This proposed conceptual framework in this study will have several potential theoretical and practical implications in the manufacturing context. First, this study will contribute to the existing body of knowledge by shedding light on the possible association between green technology innovation and sustainability in the Malaysian manufacturing solar PV industry. Second, it will enhance the applicability of the resource-based view (RBV) theory in the context of the green technology innovation-sustainability performance relationship. Third, most organisations prioritize their policies only to improve economic performance while ignoring their severe impact on the natural environment. But this study will be helpful in sustaining the balance between economic, social, and environmental performance with successful achievement. Fourth, it will help financial regulators develop proper guidelines for implementing green technology innovation and sustainability performance in the Malaysian manufacturing solar PV industry. Fifth, this study will enhance the widespread understanding of top management to comprehend green technology innovation as a significant conduit to enhance sustainability performance. Finally, this research work will try to associate the importance of green technology innovation and sustainability performance for responding to the stakeholders on growth prospects.

RESEARCH DIRECTIONS

There are several limitations proposed by this study, which point to potential areas for future research. First, future research can empirically test and validate the proposed conceptual model of this study in various industries and countries. Secondly, this study has proposed a conceptual model to be tested in Malaysian manufacturing public listed organisations. However, this conceptual framework can be modified in the context of services and privately listed organisations in future studies. It will generalize the framework of the existing study regarding the impact of green technology innovation on sustainability performance. Third, this study utilised the census method to select organisations for target sample populations for data

collection. The researchers may use the sampling method to select a sample frame in the future. The current study has not included any moderator and mediating effect between the relationship between green technology innovation and sustainability performance. Future studies can be performed by adding a moderator or mediating variable to the relationship between green technology innovation and sustainability performance. Finally, academicians will be proficient in conducting research with analysis to determine where potential advancements are needed regarding green technology innovation and sustainability performance.

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