International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2025, 15(6), 700-716.

Energy Management Practices, Renewable Energy Supply Chain, Government incentives and Environmental Performance among Manufacturing Firms

Usman Abdullahi[1,2]*, Al-Amrani Khadeem Ali Dhahi[3], Ahmad Martadha Mohamed[2], Mohamed Sukeri Khalid[2], Mahmoud Ahmad Mahmoud[4], Nura Abubakar Allumi[5]

[1]Nigeria Police Academy, Wudil, Kano State, Nigeria, [2]School of Government, Universiti Utara Malaysia, Malaysia, [3]Faculty of Business, Sohar University, Sultanate of Oman, [4]School of Business Management, Universiti Utara Malaysia, Malaysia, [5]School of Technology Management and Logistics, Universiti Utara Malaysia, Malaysia. *Email: uabdullahi171@gmail.com

Received: 25 May 2025 **Accepted:** 28 September 2025 **DOI:** https://doi.org/10.32479/ijeep.20933

ABSTRACT

This study examines how energy management practices (EMPs), renewable energy supply chains (RENSC), and government incentives (GOVI) influence environmental performance (ENVP) among manufacturing firms in Oman. Drawing on the Resource-Based View, Natural Resource-Based View, and Dynamic Capabilities Theory, EMPs and RENSC are framed as internal capabilities, while GOVI serves as an external enabler. Data from 308 firms were analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM). Results show that management commitment, energy awareness, knowledge, and audits significantly enhance environmental performance. RENSC also directly improves ENVP and mediates the EMP–ENVP relationship. Moderation analysis reveals that government incentives strengthen the positive effects of management commitment, energy knowledge, and renewable energy supply chains on environmental outcomes. Despite policy support under Vision 2040, the adoption of renewable energy technologies remains limited. The study calls for firms to invest in dynamic energy capabilities and green supply chain integration, while urging policymakers to implement targeted, performance-based incentives. Situated in an underexplored national context, this research offers novel insights into how internal resources, operational systems, and institutional support interact to drive sustainability in resource-constrained economies, thus advancing theory and practice in environmental management.

Keywords: Energy Management Practices, Renewable Energy Supply Chain, Government Incentives, Environmental Performance, Manufacturing, Oman
JEL Classifications: Q3, Q4, Q5, Q48

1. INTRODUCTION

The growing urgency of environmental sustainability and climate resilience has placed significant pressure on global industries to reassess their energy consumption patterns and environmental footprints. Among the various sectors, manufacturing remains one of the most energy-intensive and environmentally impactful, accounting for a substantial part of global green-house gas (GHG) emissions, natural resource reduction, and ecosystem degradation (Gawusu et al., 2022; Hmouda et al., 2024). Industrial energy demand is projected to rise by more than 20% by 2040, according to the International Energy Agency (IEA), with emerging nations accounting for the majority of this expansion (Dorian et al., 2020). Consequently, managing energy systems and supply chains more sustainably has become a strategic imperative for achieving environmental performance (ENVP), especially in the context of Sustainable Development Goals (SDGs), such as SDG-7 (Affordable and Clean Energy) and

SDG-12 (Responsible Consumption and Production) (Zhang and Huang, 2024). Environmental performance, as an organizational outcome, is increasingly evaluated through multidimensional indicators, including energy consumption reduction, emission control, adoption of green materials, conservation of biodiversity, and regulatory compliance (Sadiq et al., 2024). However, while firms are expected to integrate sustainability into core operations, the pathways to achieving ENVP are often complex, resource-dependent, and context-sensitive. In emerging economies, structural constraints such as limited technological capability, policy uncertainty, and high dependency on fossil fuels pose significant challenges to implementing sustainability strategies (Fernando et al., 2018; Hassanin and Knez, 2022).

A growing stream of research highlights the role of Energy Management Practices (EMPs) as a means for firms to operationalize sustainability. EMPs, including management commitment (MGTC), energy awareness (ENAW), energy knowledge (ENKW), and energy audits (ENAU), are recognized as critical internal capabilities that support firms in enhancing energy efficiency, reducing operational costs, and meeting environmental regulations (Al-Madani et al., 2024; Sadiq et al., 2024). Complementing EMPs is the concept of the Renewable Energy Supply Chain (RENSC), which represents the operational infrastructure and systems involved in sourcing, converting, distributing, and utilizing renewable energy within industrial processes (Gawusu et al., 2022; Labaran and Masood, 2023). RENSC encompasses several dimensions: renewable energy utilization (e.g., solar, wind, bioenergy integration into production), waste-to-energy conversion (e.g., transforming industrial or agricultural waste into usable energy), and energy distribution efficiency (e.g., decentralization, grid integration, and load balancing) (Klemeš et al., 2019). These components facilitate not only the decarbonization of supply chains but also the resilience of industrial energy systems amid increasing volatility in fossil fuel markets (Yavari and Bohreghi, 2025). The synergy between EMPs and RENSC offers a comprehensive pathway for manufacturing firms to advance their environmental goals while enhancing operational performance and stakeholder trust (Al-Madani et al., 2024; Fernando et al., 2018). Despite growing theoretical interest, the empirical exploration of the combined impact of EMPs and RENSC on ENVP remains limited, particularly in developing-country settings (Hmouda et al., 2024). Most existing studies have adopted a fragmented approach, focusing either on technological optimization of renewable supply chains or the behavioral and managerial dimensions of energy management. Moreover, survey-based studies that empirically examine these relationships are sparse, and those that exist are largely concentrated in East Asia or Latin America, with minimal attention to the Middle East and North Africa (MENA) region (Losada-Agudelo and Souyris, 2024). This creates an important empirical gap, especially given the region's dual dependence on energy-intensive manufacturing and its geopolitical sensitivity to energy transitions. Adding to this gap is the underexplored role of institutional support mechanisms, specifically Government Incentives (GOVI), in moderating the effectiveness of EMPs and RENSC initiatives. Policy instruments such as tax rebates, feed-in tariffs, subsidized financing, and regulatory mandates have been shown to facilitate clean energy adoption and energy efficiency programs (Zhang and Huang, 2024). Yet, the extent to which these incentives strengthen the relationship between internal energy practices and environmental outcomes is rarely examined. Studies have generally treated government support as an exogenous enabler, rather than as a dynamic moderator that could magnify or mitigate the influence of organizational strategies on sustainability performance (Al-Madani et al., 2024; Hassanin and Knez, 2022).

From a theoretical aspect, this study is based on the resource-based point of view (RBV), which states that organizations can gain a sustainable competitive edge by acquiring and using strategic resources that are valued, scarce, unique and irreplaceable (Barney, 2001). EMPs represent such internal capabilities, while the RENSC serves as a strategic configuration of physical and operational resources (Fernando et al., 2018; Sadiq et al., 2024). The Natural Resource-Based View (NRBV) extends this logic by positing that firms must proactively develop capabilities that not only exploit but also preserve environmental resources (Hart, 1995). According to NRBV, capabilities linked to pollution inhibition, product stewardship, and clean technologies are central to sustaining long-term ecological and economic performance (Al-Sheyadi et al., 2019; Gawusu et al., 2022). Besides, RBV and NRBV primarily focus on the stock of resources, often overlooking how firms dynamically respond to environmental turbulence, technological change, or evolving policy landscapes. To address this limitation, this study also incorporates the Dynamic Capabilities Theory (DCT). DCT highlights a organization's capability to combine, build, and reconfigure internal and external abilities in response to changing situations (Yavari and Bohreghi, 2025). This perspective is highly relevant to the current study's focus on manufacturing firms in Oman, where energy policies, market demands, and ecological regulations are rapidly evolving. EMPs, in this light, are not merely static routines but dynamic capabilities that enable firms to sense sustainability opportunities (e.g., energy audits, regulatory shifts), seize them (e.g., allocating financial and managerial resources toward green energy initiatives), and transform their operations (e.g., integrating RESC solutions such as solar systems or waste-to-energy infrastructure) (Labaran and Masood, 2023). Moreover, GOVI can serve as a catalyst for dynamic capability deployment, by lowering the barriers to experimentation and adoption of new energy technologies (Zhang and Huang, 2024). Firms with stronger dynamic capabilities are more likely to align government policies with internal practices, adapt to market pressures, and reconfigure their energy supply chains for improved environmental outcomes (Hassanin and Knez, 2022). For example, energy audits may evolve from a compliance requirement to a strategic tool for innovation if supported by financial subsidies or performance-linked incentives (Fernando et al., 2018). Thus, incorporating DCT provides a more comprehensive explanation of how firms in a transitioning economy like Oman can effectively bridge internal capabilities (EMPs), operational systems (RENSC), and external enablers (GOVI) to drive ENVP (Hmouda et al., 2024).

Oman, an emerging economy undergoing rapid transformation under its national development blueprint, Oman Vision 2040, aims to diversify its economy, reduce dependence on oil, and foster sustainable growth. However, persistent challenges such as regulatory inefficiencies and continued reliance on oil revenue underscore critical empirical and conceptual gaps that must be addressed to support the successful implementation of these ambitious reforms. As the country diversifies its economic base beyond oil and gas, the manufacturing sector is identified as a strategic pillar for non-oil GDP growth. At the same time, Oman faces acute environmental challenges, including high per capita energy consumption, rising emissions, and vulnerability to climate change (Al-Sarihi and Mason, 2020). In response, the government has rolled out a series of energy reforms, including subsidy rationalization, the promotion of renewable energy investments, and the introduction of national energy efficiency strategies. Despite these efforts, adoption of renewable technologies and energy management frameworks among Omani manufacturing firms remains relatively nascent. Issues such as organizational inertia, lack of energy-related expertise, and weak alignment between policy incentives and firm-level initiatives continue to hinder progress (Al-Sarihi and Cherni, 2018). In light of this, the present inquiry looks into the direct and indirect impacts in an effort to close the literature void of EMPs and RENSC initiatives on ENVP within the Omani manufacturing sector. Additionally, it evaluates the moderating effect of GOVI in influencing these interactions. In doing so, it draws upon the theoretical foundations of RBV, NRBV and DCT to frame EMPs as internal dynamic capabilities and RENSC as an operational enabler, while conceptualizing GOVI as an institutional factor that enhances resource orchestration and performance outcomes (Al-Sheyadi et al., 2019). This study offers three key contributions. First, it expands the empirical base of energy sustainability research by focusing on Oman, a context often overlooked in global sustainability discourse. Second, it offers an integrated framework that combines internal capabilities (EMPs), operational infrastructure (RENSC), and institutional incentives (GOVI) to explain variations in ENVP. Third, it provides actionable understandings for policy-makers and industry leaders striving to design targeted interventions for sustainable industrial development in resource-constrained economies.

The article is structured based on six sections as follows; the first section been the introduction, the second portion conducts a thorough analysis of relevant publications and develops research hypotheses using the RBV, NRBV, and DCT. Section three outlines the research methodology employed, including the sampling strategy, measurement constructs, and the use of Smart PLS for structural equation modeling. Section four presents the empirical results derived from the data analysis. Section five discusses the findings in light of the theoretical frameworks and contextual realities of the Omani manufacturing sector. The paper's practical and theoretical implications are highlighted in the last section, which also provides recommendations for industry practitioners and policymakers as well as future research directions.

2. LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

2.1. Theoretical Foundation

This study draws upon an integrative theoretical lens blending the RBV, NRBV, and DCT to examine how energy management practices (EMPs) and RENSC configurations jointly enhance ENVP within manufacturing firms in emerging economies, with Oman as the empirical context. The inclusion of GOVI as a moderating factor further strengthens the theoretical grounding, acknowledging the function of institutional environments in determining organizations' strategic responses to sustainability imperatives. The RBV posits that firms can achieve and sustain a competitive advantage by acquiring and deploying resources that are valuable, rare, inimitable, and non-substitutable (Barney, 2001). In this paper, EMPs are regarded as internal strategic resources that firms accumulate over time through learning, experience, and organizational routines. These practices contribute to operational efficiency and enable firms to optimize energy use, reduce emissions, and meet regulatory and stakeholder demands. Similarly, RENSC capabilities such as renewable energy utilization, waste-to-energy conversion, and energy distribution efficiency are conceived as strategic physical and technical assets that enable firms to embed sustainability across the value chain. According to RBV, when such capabilities are well-developed and difficult for competitors to replicate, they contribute to superior firm performance, including environmental outcomes. However, RBV alone is limited in accounting for environmental sustainability because it lacks explicit consideration of the natural environment and its constraints (Hart, 1995).

To address this constraint, this study features the NRBV, an expansion of RBV that places ecological sustainability at the core of resource valuation. Hart (1995) argues that a firm's competitive edge increasingly contingent on its ability to develop capabilities that align with environmental demands. The NRBV outlines three core competences: (1) Pollution control, (2) product stewardship, and (3) sustainable development. Within this framework, EMPs serve as pollution prevention mechanisms, helping firms reduce resource use and environmental harm. RESC, on the other hand, reflects sustainable development capabilities by enabling firms to change from fossil fuels to renewable energy sources and circular energy systems. Together, these capabilities position firms to comply with environmental regulations, appeal to environmentally conscious markets, and lower operational risks linked to environmental degradation. The NRBV also underscores the role of proactive, firm-driven environmental strategies. EMPs such as energy audits and specialized knowledge systems contribute to building proactive routines that go beyond compliance and seek long-term environmental value creation. In doing so, the NRBV bridges firm-level strategy with broader societal and ecological outcomes, an essential consideration in evaluating environmental performance.

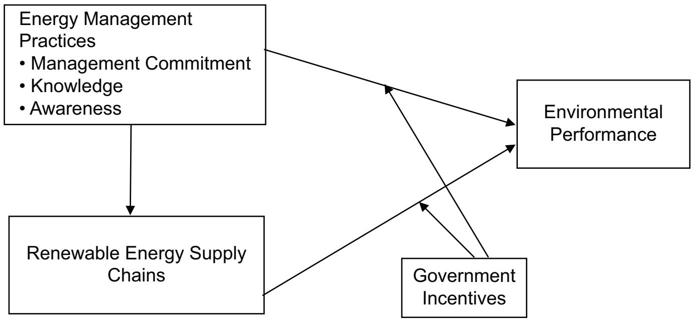
While RBV and NRBV emphasize the strategic value of internal resources, they are less explicit about how firms adapt those resources in volatile or evolving environments. This study therefore integrates DCT to explain how firms in emerging economies such as Oman, respond to shifting policy, technological, and market pressures. According to Teece et al. (2009) dynamic capabilities are the firm's abilities to sense opportunities and threats, seize them through strategic action, and reconfigure internal and external competencies to achieve congruence with a changing environment. In this study, EMPs represent dynamic abilities that allow organizations to sense and react to sustainability pressures, such as rising energy costs, stricter regulations, or evolving customer expectations. Through ongoing learning, audits, and employee engagement, these practices support continuous improvement and adaptation. Likewise, RENSC capabilities require dynamic reconfiguration of procurement, production, and distribution systems. For instance, shifting from centralized fossil-based energy to decentralized solar or bioenergy systems entails not only infrastructure investment but also managerial agility and knowledge integration. The ability to coordinate and scale these transitions reflects dynamic capability deployment. Furthermore, the role of GOVI is interpreted through a DCT lens as an enabling institutional factor that enhances firms' ability to transform energy strategies. GOVI schemes reduce uncertainty, lower investment risk, and improve firms' capacity to experiment with and adopt new technologies. Organizations with strong dynamic competences are better positioned to align such incentives with their internal strategies, thereby accelerating environmental performance outcomes.

By integrating RBV, NRBV, and DCT, this study constructs a comprehensive framework that conceptualizes EMPs and RESC as both strategic resources and dynamic capabilities (Figure 1 for the research framework). EMPs provide the behavioral and knowledge infrastructure for firms to operate efficiently and sustainably, while RENSC offers the operational configuration for clean energy integration while GI moderates these relationships. This integrated framework While Oman has introduced a suite of renewable energy policies and financial incentives, many manufacturing firms remain at an early stage of sustainability integration. Therefore, understanding how internal capabilities, operational systems, and external enablers interact to drive environmental performance is both theoretically and practically critical.

2.2. Energy Management Practices (EMPs) and Environmental Performance (ENVP)

Energy management practices (EMPs) are systematic efforts that enhance the efficiency in the use of energy, limit the consumption of energy and incorporate the use of renewable energy in to the operations of firms (Thollander and Palm, 2013). On the other hand, Singh et al. (2016) defined ENVP as the extent where firms manages their environmental aspects and their impact. This may include waste minimization, resource efficiency improvements, curbing emissions, and nurturing clean production endeavors. Environmental performance is recently viewed by organizations as an important component of their competitive profile that provide strategic advantages (Rothenberg et al., 2005).

Figure 1: Framework of the study



ENVP significantly depends on the availability of efficient and clean energy sources. It is, therefore, important to maximize the efficiency of conventional energy use during manufacturing operations, thereby minimizing CO₂ emissions (Kongbuamai et al., 2021). EMPs provide a cost-effective means of reducing greenhouse gases (GHGs) by enhancing energy efficiency. ENVP needs knowledgeable workers that have a thorough understanding of EMP functions (such as energy awareness, management commitment, energy knowledge and energy auditing) and the ability to execute them (Fernando et al., 2018). The commitment of management is also vital by providing a solid foundation for the participation of employees in energy management. Management can motivate people across the organization by demonstrating a high degree of technical expertise, giving clear instructions on the integration of energy management with business, and voicing long-term perspectives during decision-making (Rauter et al., 2017). To comprehend the complex flow of EMP, management must be fully committed to staff training and energy audits, and make constant adjustments to avoid compromising productivity (Fernando et al., 2018). Abdelaziz et al. (2011) emphasized that energy audits are fundamental to managerial energy decisions, as they help organizations gain insights into energy flow patterns. Through such audits, firms can identify areas with energy-saving potential (Schulze et al., 2016). According to NRBV theory, environmental initiatives such as reducing pollution, managing products sustainably, and promoting eco-friendly practices can serve as sources of competitive advantage for firms (Hart and Dowell, 2011; McDougall et al., 2022). This study posits that EMPs should be viewed as a core organizational resource and an evolving dynamic capability. Firms that effectively leverage EMPs can enhance their environmental performance and establish a green growth strategy that is difficult for competitors to imitate. Sustaining this competitive edge requires the integration of energy management expertise aimed at improving environmental outcomes. The technical competencies and awareness embedded in EMPs are considered rare resources that can contribute significantly to enhanced environmental performance. Thus, the following hypotheses are projected:

- H_1: Management commitment positively predicts ENVP.
- H_2: Energy awareness positively predicts ENVP.
- H_3: Energy knowledge positively predicts ENVP.
- H_4: Energy audit positively predicts ENVP.

2.3. RENSCs and Environmental Performance (ENVP)

Fernando et al. (2022) emphasized the role of waste-to-energy supply chains in generating clean energy that alleviates environmental problems such as greenhouse gas (GHG) emissions and reduce methane release from landfills. The manufacturing sector has responded by developing decarbonization strategies, including RENSCs and the adoption of alternative fuels, to curtail carbon emissions. These strategies require the modernization of production processes and the integration of efficient solutions aimed at reducing energy consumption and improving overall operational efficiency. Environmental performance in manufacturing is strongly influenced by the adoption of renewable energy. RENSC supports environmental outcomes by delivering cleaner energy sources, thereby lowering GHG emissions, optimizing energy usage, and achieving cost savings. Renewable energy also contributes to improved energy management by enhancing efficiency, decreasing carbon emissions, and encouraging environmentally responsible behavior (Kim, 2019; Mohanty, 2012). Energy and material resource management heavily relies on supply chains. The environmental effects on land, water, and air systems can be greatly reduced by lowering greenhouse gases, minimizing usage of energy, and minimizing harmful substances. Aligning sustainability practices across the supply chain is essential because it functions as a network where significant savings in energy, water, waste, and emissions can be accomplished (Cerchione and Esposito, 2016). A sustainable supply chain requires active participation across all stakeholders in the renewable energy network, ensuring alignment of resource flows, stocks, and sustainability goals through well-established corporate environmental strategies (Fontes et al., 2018). Environmental performance focuses on safeguarding environmental assets such as air quality, water resources, soil health, ecosystems, and energy conservation, aligning with broader sustainability targets and efficient resource usage (Gaitán et al., 2013). It entails assessing environmental risks, such as emission levels and their ecological impact. Inefficient use of vital resources like water and energy negatively affects the broader environmental system, including soil, water, and atmospheric quality. Conversely, resource efficiency promotes reductions in energy consumption, hazardous waste production, and emissions, all while sustaining firm-level profitability and productivity. Environmental performance indicators are often reflective of societal concerns regarding ecological impact and sustainability (Boons and Wagner, 2009). For instance, the adoption of solar energy empowers firms to shift their energy profiles, bolster energy resilience and stimulate green economic development, thereby increasing operational efficiency across the system (Abdelaziz et al., 2011; Mekhilef et al., 2011).

- H_5: RENSCs positively and significantly predicts ENVP.

2.4. Energy Management Practices (EMPs) and RENSCs

EMPs are regarded as internal capabilities that developed over time and eventually became embedded tacit resources of the organization (Fernando et al., 2018; Gunarathne and Lee, 2021). These resources, formed through complex social interactions, are unique, difficult to substitute, and scarce. Firms adopt energy management to achieve a competitive advantage, which increasingly depends on technological advancements such as RENSCs. The manufacturing sector is responsible for more than 36 percent of global CO_2 emissions and consumes nearly half of the world's total energy supply (Rahman et al., 2016). Moreover, the rise in energy costs, stricter environmental regulations, and global concerns over energy security have created pressure to enhance industrial energy efficiency (Aktar et al., 2024). As a result, manufacturers are striving to identify cost-effective strategies to optimize energy use in their operations (Rahman et al., 2016).

Consequently, RENSC also plays a supportive role in EMPs by promoting energy security within supply chains, enhancing efficiency, and lowering carbon emissions through renewable energy sources (Fernando et al., 2018). Effective energy management seeks to reduce energy consumption, tackle efficiency obstacles, and embed a conservation-oriented mindset within organizational operations (Afum et al., 2020; Fernando et al., 2018). For energy management to deliver effective outcomes, it must be supported by sustainable energy sources (Gogoi et al., 2022; Olatomiwa et al., 2016). According to RBV theory, firms should utilize their available resources in a way that builds distinctive capabilities, creating a competitive advantage that rivals cannot easily replicate (Al-Madani et al., 2024). The ability to harness new resources such as renewable energy can lead to new organizational capabilities essential for long-term success. Ganesh and Xu (2022) emphasized that energy management plays a crucial role in creating energy-efficient operations. Management commitment serves as a key driver and facilitator of energy information, awareness, and audit activities within firms. Fernando et al. (2018) also established a link between management commitment and the successful implementation of renewable energy. Thus, we hypothesized that.

- H_6: Management commitment is positively and significantly associated with RENSC.
- H_7: Energy awareness is positively and significantly associated with RENSC.
- H_8: Energy knowledge is positively and significantly associated with RENSC.
- H_9: Energy auditing is positively and significantly associated with RENSC.

2.5. Mediating Role of RENSC

The integration of EMPs may not always directly translate to enhanced environmental performance unless operationalized through strategic supply chain mechanisms. RENSC, by acting as an implementation platform, may mediate the effect of EMPs on environmental outcomes. Informed by NRBV and DCT, the alignment of EMPs with RENSC elements facilitates the translation of internal energy capabilities into tangible environmental benefits. The NRBV and DCT suggest that firms attain environmental and competitive advantages when internal resources such as EMPS are reconfigured and aligned effectively with external resources such as RENSC (Teece et al., 1997). Consequently, the RESC will serve as a mediating mechanism that assist firms to translate their energy management practices into environmental performance i.e., waste minimization, resource efficiency improvements, curbing emissions, and nurturing clean production endeavors (Moktadir and Rahman, 2022). In line with the NRBV, ENVP is an important component of strategic and competitive advantages (Rothenberg et al., 2005).

Empirical studies by Fernando et al. (2018) and Patel et al. (2022) suggesting that the environmental impact of EMPs is often amplified when supported by renewable technologies and systemic distribution improvements. Moreover, the integration of RENSC practices was found to substantially influence firms' sustainability practices on environmental performance aspects (Ning et al., 2025). RENSC decisions were also found to be fundamental in closing the operational efficiency loop on environmental sustainability (Govindan et al., 2015). This underscores the importance of investigating RENSC as a mediating mechanism. Thus, we stated that:

- H_{10a}: RENSC mediates the relationship between MGTC and ENVP.

- H_{10b}: RENSC mediates the relationship between ENAW and ENVP.
- H_{10c}: RENSC mediates the relationship between ENKW and ENVP.
- H_{10d}: RENSC mediates the relationship between ENAU and ENVP.

2.6. Moderating Role of Government Incentives

Government incentives are widely recognized as crucial drivers in linking organizational capabilities, such as EMPs and RENSCs to sustainability outcomes. Financial rewards, subsidies, and supportive policies directly promote the adoption of cleaner technologies, efficient resource use, and supply chain innovation, thereby enhancing ecological and business sustainability (Lin et al., 2024; Vazifeh et al., 2023). Evidence from regions like Malaysia and the Asia Pacific highlights the effectiveness of these incentives in reducing ecological footprints and advancing green transitions. Moreover, game-theoretic and modeling studies confirm that well-structured government interventions can align stakeholder interests, improve energy practices, and accelerate progress toward sustainable development goals (Amiri-Pebdani et al., 2022). Drawing from DCT, such incentives play a pivotal role in enhancing firms' ability to sense opportunities, mobilize resources, and reconfigure energy strategies in response to environmental and policy shifts. Through subsidies, feed-in tariffs, tax reliefs, and regulatory support, governments reduce the financial and operational uncertainty often associated with environmental innovations and clean energy transitions. Fundamentally, energy policies seek to balance ecological sustainability with responsible resource use, environmental preservation, and the delivery of reliable and efficient energy systems. Regulatory mechanisms such as feed-in tariffs (FITs) have been widely adopted in countries like Germany, the United States, and Malaysia, with proven effectiveness in promoting renewable energy adoption and reducing investment risks in the energy sector (Al-Madani et al., 2024). However, despite the presence of such policy instruments, the actual impact of government incentives in moderating energy-related decision-making among firms, especially in emerging economies like Oman, remains ambiguous.

In Oman, a suite of clean energy policies has been introduced under the country's Vision 2040 framework to accelerate the transition to sustainable energy. Nevertheless, the industrial uptake of energy-efficient and renewable energy solutions remains sluggish. Scholars note that barriers such as limited managerial awareness, lack of technical expertise, and investment hesitancy due to uncertain returns often hinder the effectiveness of such policy interventions (Al-Madani et al., 2024; Fernando et al., 2018). In this regard, GOVIs may function not only as financial tools but also as motivational and informational levers that influence how manufacturing firms adopt and integrate EMPs and RENSCs into their operations. As such, the presence of government incentives is likely to reinforce the effectiveness of EMPs by encouraging energy audits, awareness campaigns, and employee training initiatives. In the case of renewable energy integration, the government plays an even more direct role by bridging the gap between fossil-based energy systems and RENSCs. Policies such as net metering, competitive bidding, and wheeling arrangements are central to improving the technical and financial viability of renewable energy deployment across the supply chain. For instance, the Palestinian government has implemented various schemes, including licensing, FITs, and solar project financing to stimulate RENSC adoption (Morrar et al., 2025). Similarly, Indonesia and Egypt have leveraged loans, tax breaks, and R&D incentives to foster industrial green transitions (Maghyereh et al., 2025; Nchake, 2025). The importance of such institutional support is well-supported in prior research, which has shown that policies and incentives are often decisive in firms' willingness and ability to embrace sustainable.

In emerging economies, where resource constraints often limit the internal capacity for sustainability, government support can mitigate cost barriers and de-risk green innovation efforts (Khattak et al., 2022; Monasterolo and Raberto, 2018). Subsidies and incentives reduce R&D expenditure, accelerate technology adoption, and support firms in restructuring traditional operations toward cleaner alternatives (Květoň and Horák, 2018). Empirical evidence further confirms that such support enhances organizational engagement in energy-saving behavior, boosts psychological readiness for green transitions, and positively influences firm-level environmental performance (Gillingham and Sweeney, 2012). From the NRBV, such external support mechanisms can catalyze the advancement of organization-specific environmental abilities, particularly when firms are equipped with managerial readiness and strategic orientation toward sustainability. In line with this, government incentives can activate or enhance the dynamic linkages between EMPs, RENSC implementation, and desired environmental outcomes by lowering adoption risks and aligning firm behavior with national sustainability goals. Therefore, this study posits that Government Incentives serve as a boundary condition that strengthens the impact of EMPs and RENSCs on ENVP in Omani manufacturing firms. Specifically, firms operating under supportive governmental programs are more likely to achieve superior environmental outcomes through enhanced energy management and renewable integration. Accordingly, it is hypothesized that:

- H_{11a}: The positive effect of Management Commitment on EP will be stronger when government incentives are higher.
- H_{11b}: The positive effect of Energy Knowledge on EP will be stronger when government incentives are higher.
- H_{11c}: The positive effect of Energy Awareness on EP will be stronger when government incentives are higher.
- H_{11d}: The positive effect of Energy Audit on EP will be stronger when government incentives are higher.
- H_{11e}: The positive effect of the RESC on EP will be stronger when government incentives are higher.

3. METHODOLOGY

3.1. Research Design

This study employed a quantitative, cross-sectional survey design to investigate the relationship between EMPs, RENSC, GOVI, and ENVP among manufacturing firms in Oman. A structured questionnaire was used to gather data, as this method is widely recognized for its effectiveness in examining organizational-level phenomena and enabling statistical analysis of complex variable relationships.

3.2. Instrument Development

A structured questionnaire was developed by adapting measurement items from validated scales in previous studies to ensure both construct reliability and content validity. The items measuring EMPs' dimensions such as management commitment, energy awareness, energy knowledge, and energy audits were adapted from Al-Madani et al. (2024). For the RENSC, 5 items were also drawn from Al-Madani et al. (2024) and Mohamed Nazief Haggag Kotb Kholaif et al. (2022). GOVI was measured using 5 items adapted from (Khattak and Shah, 2021). The ENVP was measured using 5 items adapted from Al-Madani et al. (2024) and Laosirihongthong et al. (2013). All items were assessed using a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). To enhance content validity, the draft questionnaire was reviewed by a panel of experts comprising academics and industry professionals with experience in sustainability and industrial energy management. Their feedback informed revisions to improve clarity, contextual relevance, and flow.

3.3. Sampling and Population

The unit of analysis was the organization, specifically manufacturing firms operating in Oman. The target respondents included individuals in senior and technical decision-making roles, such as Chief Executive Officers (CEOs), Managing Directors, R&D managers, Environmental Health and Safety (EHS) officers, energy managers, operations managers, sustainability officers, and plant engineers. These professionals were chosen for their direct involvement in energy and environmental initiatives within their organizations. The sampling frame was informed by data from the National Centre for Statistics & Information (NCSI), which reports that over 9,000 manufacturing firms operate across Oman (NCSI, 2023). Stratified random sampling was employed to ensure broad representation across various industrial sectors, including food processing, chemicals, plastics, and metal manufacturing. Contact information was obtained from the Oman Chamber of Commerce and Industry (OCCI), which maintains the official registry of licensed businesses in the country.

3.4. Data Collection Procedures

A total of 442 questionnaires were distributed via email to manufacturing firms across Oman. Follow-up emails and phone calls were made to improve the response rate. In total, 329 responses were returned. Following initial screening, 21 responses were excluded due to excessive missing data or repetitive response patterns (e.g., straight-lining), resulting in 308 valid cases for analysis. The final dataset was further examined for missing values. The pattern of missingness was assessed using Little's MCAR test, which confirmed that the data were missing completely at random (Little, 1988). Given that the proportion of missing data was minimal and MCAR conditions were satisfied, listwise deletion was applied to ensure the reliability of statistical estimates (Hair et al., 2022). We adhered to ethical standards by obtaining respondents' permission and signed consent before administering the survey. Their privacy and demographic data were protected, and they were informed that the study was solely for academic purposes. Confidentiality was assured, and participants were encouraged to respond fully and honestly. Ethical approval was obtained from the Ethics Committee of Sohar University, the second author's affiliated institution, in accordance with the University's Research Ethics and Biosafety Policy. The study adhered to the ethical principles outlined in the Declaration of Helsinki.

3.5. Bias Control and Validity Checks

To reduce common method bias, procedural steps such as ensuring respondent anonymity and randomizing questionnaire items were implemented. Harman's single-factor test showed no dominant factor, indicating minimal CMB risk. To check for non-response bias, early and late responses were compared using independent t-tests, revealing no significant differences across key variables.

4. DATA ANALYSIS

Data analysis followed a two-phase approach, incorporating both descriptive and inferential techniques. Descriptive statistics were first generated using IBM SPSS Statistics version 30 to summarize sample characteristics and detect any anomalies. To examine the demographic characteristics of the respondents, data from 308 manufacturing firms in Oman were analyzed using SPSS version 30. Table 1 shows that the participating firms represented a range of industries, with the majority from the chemical (17.9%), engineering (15.3%), and oil and gas (14.6%) sectors, followed by dairy, pharmaceutical, textiles, pulp and paper, fertilizer, and sugar. Most firms (44.8%) had been established for over 12 years, indicating a predominance of mature organizations, while 11.0% were relatively new, operating for <4 years. In terms of company size, 53.2% were medium-sized, 29.9% small, and 6.5% micro-enterprises, suggesting that medium firms form the backbone of Oman's manufacturing sector. Employee distribution closely followed this trend, with 34.4% of firms employing between 101–200 workers and 31.8% employing 31–100. Ownership structures were primarily private limited companies (55.8%), followed by public limited firms (22.1%) and partnerships (15.6%). Regarding energy sources, solar panel electricity was the most utilized renewable source (32.8%), followed by solar water heaters (29.9%) and solar electricity (16.6%). Use of biomass boilers (11.7%) and wind turbines (9.1%) remained limited. In the renewable energy supply chain, solar energy dominated (39.6%), with wind (18.5%), biomass (15.6%), and biogas energy (11.0%) trailing behind, while hydropower accounted for only 8.8%. These findings reflect the growing reliance on solar-based technologies in Oman's manufacturing sector, with varied adoption of alternative sources across firms.

To test the hypothesized relationships, Partial Least Squares Structural Equation Modeling (PLS-SEM) was conducted using SmartPLS 4.0. This method was deemed appropriate given its robustness in handling complex models involving mediation and moderation, its suitability for theory building, and its tolerance for non-normal data and modest sample sizes (Wang et al., 2023). PLS-SEM analysis proceeded in two stages. The first stage focused on evaluating the measurement model to establish the reliability and validity of the constructs. This was followed by structural model assessment to test the significance and predictive strength of the hypothesized relationships. Given the reliance on a single data source, it was necessary to address the potential for common method bias (CMB). To this end, the full collinearity assessment approach proposed by Kock and Lynn (2012) and Kock (2015) was applied. This technique involves regressing each latent variable on a common hypothetical factor and examining the resulting variance inflation factors (VIFs). In line with their recommendation, all VIF values in this study were below the threshold of <5 (Hair et al., 2021) (Table 2), indicating that common method variance is unlikely to pose a significant threat to the validity of the results.

4.1. Measurement Model

In line with the two-step analytical procedure outlined by Anderson and Gerbing (1988) the evaluation began with an assessment of the measurement model before proceeding to hypothesis testing via structural model analysis. This approach ensures that the constructs used in the study demonstrate adequate reliability and validity before interpreting their interrelationships (Ramayah et al., 2018).

To assess convergent validity and internal consistency reliability, we examined item loadings, average variance extracted (AVE), and composite reliability (CR). Following standard thresholds, item loadings should be ≥ 0.50, AVE should be ≥ 0.50, and CR should be ≥ 0.70 benchmark (Hair Jr et al., 2022). As presented in Table 3, all AVE values met the 0.50 cutoff, and all CR values were above 0.70, indicating satisfactory internal consistency. Most item loadings exceeded the recommended level of 0.708, with only a few slightly below that threshold, which is still acceptable when overall construct reliability is strong (Figure 2). Next, discriminant validity was examined using the Heterotrait-Monotrait ratio of correlations (HTMT), as proposed by Henseler et al. (2015) and further refined by Franke and Sarstedt (2019). HTMT values below 0.85 are indicative of strong discriminant validity under the stricter criterion, while values below 0.90 are considered acceptable in more lenient interpretations. As shown in Table 4, all HTMT values fell below the 0.85 threshold, suggesting that respondents clearly differentiated among the constructs. Taken together, the evidence from both convergent and discriminant validity assessments affirms that the measurement model is both psychometrically sound and appropriate for subsequent structural analysis.

Table 1: Demographic profile

Variable	Classification	n	%
Type of Company	Chemical	55	17.9
	Dairy	38	12.3
	Engineering	47	15.3
	Fertilizer	21	6.8
	Oil and Gas	45	14.6
	Pharmaceutical	31	10.1
	Pulp and Paper	22	7.1
	Sugar	24	7.8
	Textiles	25	8.1
Years of Establishment	Less than 4 years	34	11
	4–8 years	56	18.2
	9–12 years	80	26
	More than 12 years	138	44.8
Company Size	Micro	20	6.5
	Small	92	29.9
	Medium	164	53.2
	Other	32	10.4
Number of Employees	1–30	41	13.3
	31–100	98	31.8
	101–200	106	34.4
	201 and above	63	20.5
Ownership	Private Limited	172	55.8
	Public Limited	68	22.1
	Partnership	48	15.6
	Others	20	6.5
Renewable Source of Energy	Wind Turbine	28	9.1
	Solar Water Heater	92	29.9
	Solar Panel Electricity	101	32.8
	Solar Electricity	51	16.6
	Biomass Boiler	36	11.7
Type of Renewable Energy Supply Chain	Solar Energy	122	39.6
	Hydropower	27	8.8
	Biomass Energy	48	15.6
	Biogas Energy	34	11
	Wind Energy	57	18.5

Table 2: Full collinearity testing

Constructs	ENAU	ENAW	ENK	ENVP	GOVI	MGTC	RENSC
VIF	2.269	1.975	1.888	2.640	2.437	3.179	1.431

Table 3: Measurement model result

Constructs	Items	Loadings	CA	CR	AVE
Energy Audit	ENAU1	0.749	0.770	0.852	0.591
	ENAU2	0.748			
	ENAU3	0.792			
	ENAU4	0.784			
Energy Awareness	ENAW1	0.753	0.809	0.867	0.567
	ENAW2	0.747			
	ENAW3	0.764			
	ENAW4	0.762			
	ENAW5	0.736			
Energy Knowledge	ENK1	0.795	0.845	0.895	0.681
	ENK2	0.804			
	ENK3	0.862			
	ENK4	0.838			
Environmental Performance	ENVP1	0.760	0.793	0.858	0.548
	ENVP2	0.718			
	ENVP3	0.787			
	ENVP4	0.763			
	ENVP5	0.667			
Government Incentive	GOVI1	0.775	0.818	0.873	0.579
	GOVI2	0.787			
	GOVI3	0.702			
	GOVI4	0.751			
	GOVI5	0.787			
Management Commitment	MGTC1	0.602	0.763	0.842	0.517
	MGTC2	0.787			
	MGTC3	0.743			
	MGTC4	0.740			
	MGTC5	0.711			
Renewable Energy Supply Chain	RENSC1	0.725	0.775	0.847	0.528
	RENSC2	0.603			
	RENSC3	0.712			
	RENSC4	0.762			
	RENSC5	0.815			

Figure 2: Measurement model

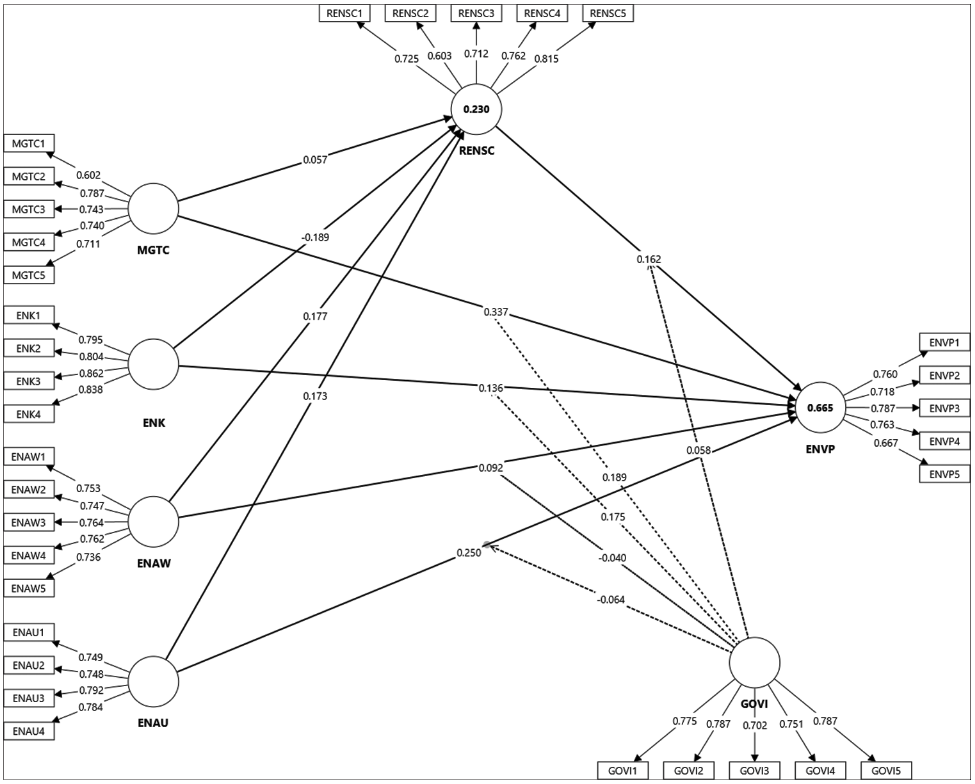


Table 4: Discriminant Validity (HTMT)

Constructs	1	2	3	4	5	6	7
1. ENAU							
2. ENAW	0.838						
3. ENK	0.503	0.425					
4. ENVP	0.794	0.705	0.468				
5. GOVI	0.712	0.592	0.694	0.778			
6. MGTC	0.778	0.709	0.784	0.824	0.847		
7. RENSC	0.508	0.488	0.430	0.631	0.462	0.485	

4.2. Structural Model

Before assessing the structural model, Mardia's tests for multivariate skewness and kurtosis were conducted to examine normality, following Cain et al. (2017). The results confirmed non-normality, with significant skewness ($\beta = 36.489$, $P < 0.01$) and kurtosis ($\beta = 160.915$, $P < 0.01$). Consequently, a non-parametric bootstrapping procedure with 10,000 resamples was applied, as recommended by Becker et al. (2023) to ensure robust inference under non-normal conditions typical of survey data. In line with Hahn and Ang (2017) critique of sole reliance on p-values, a combination of indicators, including path coefficients, standard errors, t-values, p-values, effect sizes (f^2), and confidence intervals, was used to evaluate the hypotheses. This comprehensive approach provides a more reliable interpretation of the structural relationships. The detailed results are summarized in Tables 5 and 6 and depicted in Figure 3.

In the first stage of structural model evaluation, the influence of the five antecedents, on ENVP was assessed. The model explained 66.5% of the variance in ENVP ($R^2 = 0.665$; $Q^2 = 0.602$), indicating a moderate level of explanatory power. All the five predictors demonstrated statistically significant and positive effects on ENVP: MGTC -> ENVP ($\beta = 0.337$, $P < 0.01$), ENK -> ENVP ($\beta = 0.136$, $P = 0.001$), ENAW -> ENVP ($\beta = 0.092$, $P = 0.047$), ENAU -> ENVP ($\beta = 0.250$, $P < 0.01$), and RENSC -> ENVP ($\beta = 0.162$, $P < 0.01$). Equally, the results showed that RESC accounted for 23% of the variance in ENVP ($R^2 = 0.230$; $Q^2 = 0.188$), suggesting a modest but meaningful explanatory power. These findings provide empirical support for hypotheses H1, H2, H3, H4 and H5. Subsequently, the impact of the four EMPs on RESC was examined. The results showed that two of the four predictors demonstrated statistically significant and positive effects on RESC: ENAW -> RENSC ($\beta = 0.177$, $P = 0.030$), ENAU -> RENSC ($\beta = 0.173$, $P = 0.015$), indicating support for H7 and H9. However, the relationship between MGTC -> RENSC ($\beta = 0.057$, $P = 0.331$), and ENK -> RENSC ($\beta = -0.189$, $P = 0.004$), were not significant, thus, H6 and H8 were not supported (Table 5).

To evaluate the mediation hypotheses, the bootstrapping procedure recommended by Preacher and Hayes (2004) was employed. This method involves estimating the indirect effects and examining whether the bias-corrected confidence intervals exclude zero. If the interval does not straddle zero, the mediating effect is considered statistically significant. As presented in Table 6, two of the indirect paths were found to be significant: ENAW -> RENSC -> ENVP ($\beta = 0.029$, $P = 0.045$), ENAU -> RENSC -> ENVP ($\beta = 0.028$, $P = 0.043$). In these cases, the 95% bias-corrected confidence intervals did not include zero, providing additional support for the mediating role of RESC. These results confirm the mediation effects proposed in hypotheses H10b, and H10d. Contrarily, the other two indirect paths were not statistically significant: MGTC -> RENSC -> ENVP ($\beta = 0.009$, $P = 0.319$), ENK -> RENSC -> ENVP ($\beta = -0.031$, $P = 0.030$), hence, H10a and H10c are not supported.

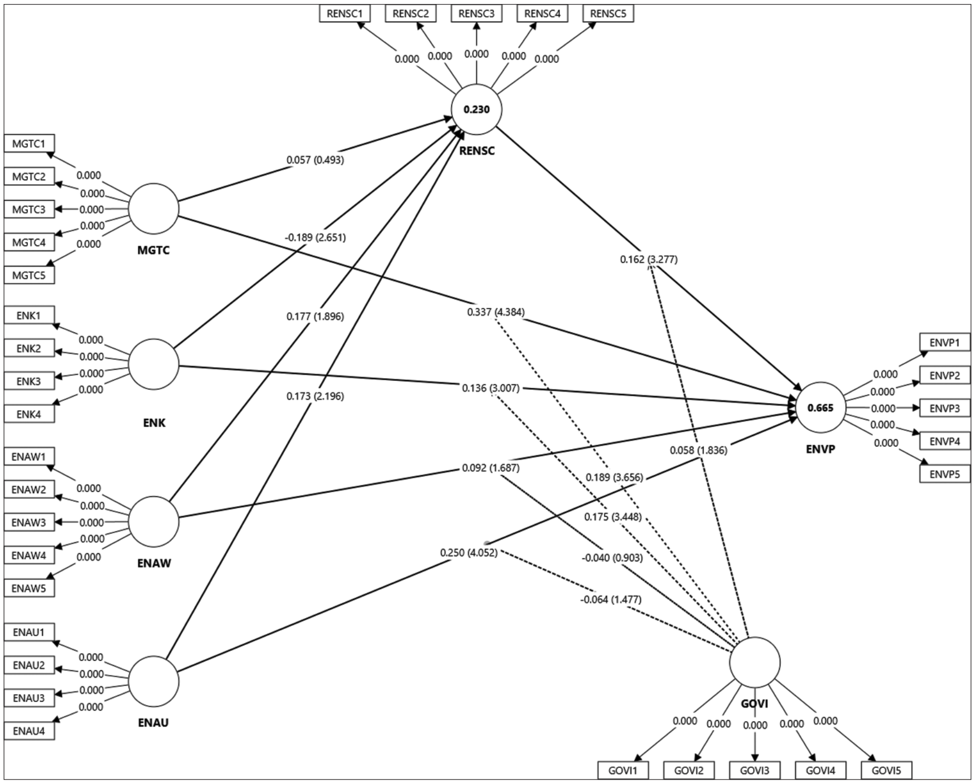
Table 5: Hypotheses testing (direct relationships)

Hypothesis	Relationship	Std-Beta	Std-error	t-values	P-values	CI-LL	CI-UL	F2
H_1	MGTC -> ENVP	0.337	0.077	4.384	0.000	0.197	0.455	0.114
H_2	ENAW -> ENVP	0.092	0.055	1.687	0.047	0.009	0.186	0.012
H_3	ENK -> ENVP	0.136	0.045	3.007	0.001	0.050	0.204	0.028
H_4	ENAU -> ENVP	0.250	0.062	4.052	0.000	0.142	0.351	0.074
H_5	RENSC -> ENVP	0.162	0.050	3.277	0.001	0.079	0.247	0.049
H_6	MGTC -> RENSC	0.057	0.116	0.493	0.311	−0.121	0.260	0.002
H_7	ENAW -> RENSC	0.177	0.094	1.896	0.030	0.009	0.316	0.021
H_8	ENAU -> RENSC	0.173	0.079	2.196	0.015	0.048	0.302	0.019
H_9	ENK -> RENSC	−0.189	0.071	2.651	0.004	−0.288	−0.060	0.028

Table 6: Hypotheses testing (mediation and moderating relationships)

Hypothesis	Relationship	Std-Beta	Std-error	t-values	P-values	CI-LL	CI-UL	F2
H_{10a}	MGTC -> RENSC -> ENVP	0.009	0.020	0.472	0.319	−0.021	0.048	0.000
H_{10b}	ENAW -> RENSC -> ENVP	0.029	0.017	1.701	0.045	0.011	0.066	0.001
H_{10c}	ENK -> RENSC -> ENVP	−0.031	0.016	1.884	0.030	−0.074	−0.014	0.001
H_{10d}	ENAU -> RENSC -> ENVP	0.028	0.016	1.721	0.043	0.008	0.061	0.001
H_{11a}	GOVI x MGTC -> ENVP	0.189	0.052	3.656	0.000	0.101	0.277	0.067
H_{11b}	GOVI x ENK -> ENVP	0.175	0.051	3.448	0.000	0.085	0.254	0.047
H_{11c}	GOVI x ENAW -> ENVP	−0.040	0.045	0.903	0.184	−0.119	0.028	0.006
H_{11d}	GOVI x ENAU -> ENVP	−0.064	0.043	1.477	0.071	−0.141	−0.006	0.020
H_{11e}	GOVI x RENSC -> ENVP	0.058	0.031	1.836	0.034	0.007	0.118	0.014

Figure 3: Structural model



Conversely, the moderating role of GOVI on the relationship between the predictors and ENVP was assessed through interaction effects, as presented in Table 6. The results reveal varying levels of statistical significance and practical relevance across the hypothesized paths. GOVI significantly moderated the relationship between MGTC and ENVP (H11a: $\beta = 0.189$, $P < 0.001$), with a small-to-moderate effect size ($f^2 = 0.067$). Similarly, a significant interaction was observed between ENK and ENVP (H11b: $\beta = 0.175$, $P < 0.001$), also accompanied by a small effect size ($f^2 = 0.047$). However, the moderating effect of GOVI on the relationship between ENAW and ENVP was not significant (H_{11c}: $\beta = -0.040$, $P = 0.184$; $f^2 = 0.006$), indicating no meaningful interaction. Likewise, the interaction between ENAU and ENVP was marginally insignificant (H_{11d}: $\beta = -0.064$, $P = 0.071$; $f^2 = 0.020$). Finally, the interaction between GOVI and RENSC showed a weak but statistically significant moderating effect on ENVP (H_{11e}: $\beta = 0.058$, $P = 0.034$; $f^2 = 0.014$). In summary, hypotheses H_{11a}, H_{11b}, and H_{11e} were supported, whereas H_{11c} and H_{11d} were not.

4.3. PLS-predict

To evaluate the model's out-of-sample predictive capability, the PLSpredict procedure was performed using a 10-fold cross-validation approach, as recommended by Shmueli et al. (2019). Table 7 compares the root mean squared error (RMSE) values from the PLS-SEM model and a linear model (LM) benchmark across individual items. The results show that for all items related to Environmental Performance (ENVP1–ENVP5) and Renewable Energy Supply Chain (RENSC1–RENSC5), the RMSE values from the PLS-SEM model were consistently lower than those from the LM model. Corresponding PLS-LM differences were all negative, ranging from (−0.003 to −0. 041). According to the evaluation criteria, where all prediction errors from the PLS model are lower than those from the linear benchmark, the model demonstrates strong predictive power. Thus, the findings confirm that the proposed model has robust predictive relevance for both environmental performance and renewable energy practices.

4.4. Model Fit Assessment

To assess the overall goodness-of-fit of the structural model, the standardized root mean squared residual (SRMR) was evaluated for both the saturated and estimated models. The SRMR value was 0.065 for both models, which is below the recommended threshold of 0.08. This indicates a satisfactory model fit and suggests that the differences between the observed and predicted correlation matrices are minimal (Benitez et al., 2020). The consistency of SRMR values across both models further reinforces the robustness of the model's structural specification.

4.5. Interaction Plot

To illustrate the significant moderating effects (H_{11a}, H_{11b}, and H_{11e}), interaction plots were generated following Dawson (2014) and Becker et al. (2023). As shown in Figure 4, the positive relationship between management commitment and environmental performance is stronger when government incentives are high. Similarly, Figure 5 shows that energy knowledge yields greater environmental outcomes under strong policy support. Figure 6 indicates that renewable energy supply chain practices also lead to improved environmental performance when government incentives are more favorable.

5. DISCUSSION

Environmental sustainability in the industrial sector has garnered increasing attention from scholars and policy actors alike, particularly in the context of global climate imperatives and energy transitions (Gawusu et al., 2022). This study provides novel empirical insights into how EMPs, RENSC, and government incentives interplay to shape the ENVP of manufacturing firms in Oman, an emerging economy undergoing structural transformation. Drawing upon the integrated lenses of the RBV, NRBV, and DCT, the study offers a multi-layered understanding of firm-level sustainability capabilities. Specifically, the empirical findings first confirmed the significant and positive association between management commitment and environmental performance. This supports prior research indicating that committed leadership plays a foundational role in the diffusion of sustainability principles across organizational processes (Rauter et al., 2017). Top management not only allocates the necessary resources for energy efficiency initiatives but also signals a long-term vision that aligns environmental goals with corporate strategy. In the context of Oman's energy-intensive manufacturing sector, where sustainability awareness remains nascent, managerial commitment serves as a transformative force that activates organizational buy-in and guides performance standards toward green outcomes.

Table 7: PLS predict results

Item	Q² predict	PLS-SEM_ RMSE	LM_ RMSE	PLS-LM
ENVP1	0.330	0.549	0.552	−0.003
ENVP2	0.315	0.551	0.581	−0.030
ENVP3	0.378	0.513	0.541	−0.028
ENVP4	0.360	0.511	0.525	−0.014
ENVP5	0.228	0.603	0.617	−0.014
RENSC1	0.094	0.704	0.737	−0.033
RENSC2	0.041	0.836	0.877	−0.041
RENSC3	0.077	0.745	0.766	−0.021
RENSC4	0.138	0.617	0.632	−0.015
RENSC5	0.124	0.683	0.722	−0.039

Second, the study finds robust positive relationships between energy awareness, knowledge, and auditing practices with

Figure 4: Interaction plot for MGTC * Government incentive

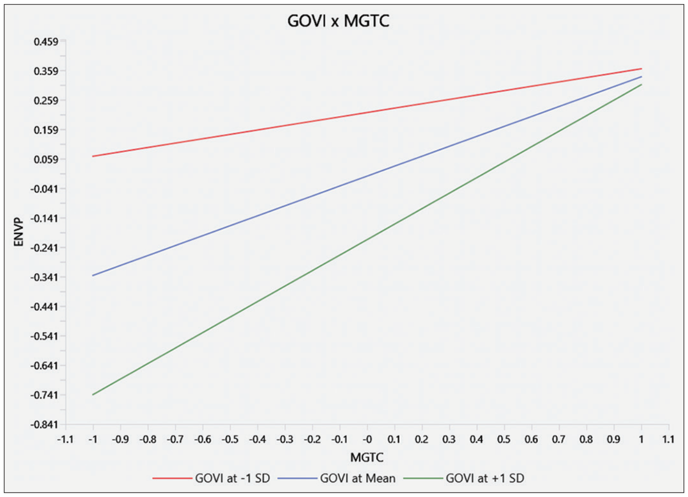


Figure 5: Interaction plot for ENK * Government incentive

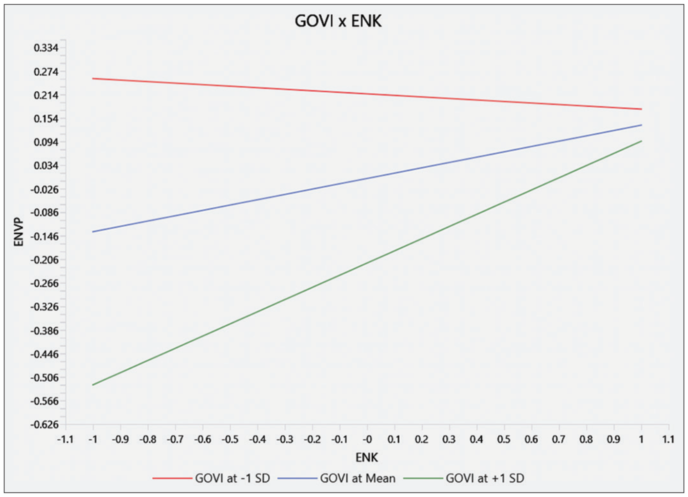
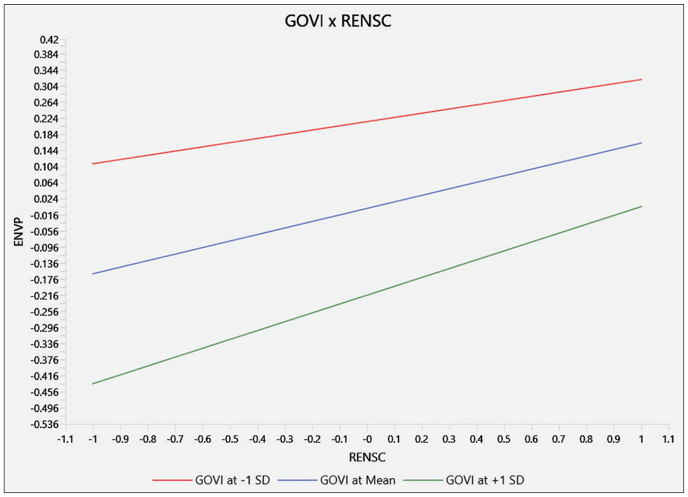


Figure 6: Interaction plot for RENSC * Government incentive



environmental performance. This finding resonates with work conducted in Malaysia Al-Madani et al. (2024) and Egypt Mohamed Nazief Haggag Kotb Kholaif et al. (2022) which underscores the enabling role of internal energy-related expertise and operational transparency. Employees who possess contextual energy awareness and are equipped with auditing tools are better positioned to identify inefficiencies and implement corrective measures. These practices facilitate a culture of continuous improvement, where energy consumption patterns are not only monitored but optimized in real time. As the NRBV suggests, these elements represent pollution-preventive competencies that simultaneously reduce environmental harm and support long-term firm competitiveness (McDougall et al., 2022). Third, the findings reaffirm the positive effect of RENSC on ENVP. This aligns with previous studies that conceptualize RENSC not merely as a supply-side intervention, but as a strategic platform for enabling clean energy transitions (Fernando et al., 2022). Firms that have invested in decentralized solar systems, waste-to-energy technologies, or biomass networks are better equipped to decouple production growth from environmental degradation. Moreover, the integration of RENSC elements reflects a higher-order capability to reconfigure energy systems in response to both environmental and market shifts, a hallmark of the DCT framework (Teece et al., 1997). In the Omani context, where conventional fossil-fuel dependency remains high, the adoption of RENSC represents a forward-looking strategic choice that offers not only operational resilience but also reputational capital in a globally conscious market.

Importantly, the study establishes a significant moderating effect of government incentives on the relationship between EMPs, RENSC and ENVP. This echoes recent literature that positions policy instruments such as feed-in tariffs, green tax rebates, and subsidized technology financing as critical levers for accelerating clean energy adoption (Zhang and Huang, 2024). In this case, GI acts as a contextual enabler, particularly relevant in emerging economies where financial and technological constraints often hinder environmental initiatives. The alignment between internal strategic capabilities and external institutional support is pivotal, as firms with stronger internal preparedness are more likely to leverage government schemes effectively. As observed in both Malaysia and Egypt, the synergy between institutional support and internal capability development enhances ecological outcomes and fosters systemic change. Furthermore, the interaction between EMPs and RENSC suggests a dynamic complementarity. Firms with mature EMPs are not only better positioned to deploy RENSC components but also to adapt them over time, based on energy audits and real-time feedback. This reflects the dynamic capability of sensing, seizing, and transforming internal systems to respond to sustainability pressures (Yavari and Bohreghi, 2025). For instance, energy audits, initially introduced as compliance tools, can evolve into innovation platforms when supported by GI and coupled with a RENSC framework. Such firms exhibit a proactive posture toward sustainability, viewing environmental initiatives not as costs, but as opportunities for process innovation and value creation.

Finally, the study offers valuable contributions to the ongoing conversation on sustainability transitions in the Global South. While most empirical research on energy management and green supply chains is concentrated in East Asia or Western economies, this study extends the analytical lens to Oman, providing contextual richness and policy-relevant insights. The country's evolving regulatory landscape under Vision 2040, coupled with structural constraints like fossil fuel reliance and limited industrial diversification, creates a unique backdrop against which to examine the interplay between internal firm capabilities and institutional scaffolding. The results indicate that while internal capacities such as EMPs and RESC are necessary, they are insufficient without strategic alignment with government policy. Therefore, holistic policy design that fosters interdependence between firm-level innovation and public incentives is critical for achieving sustainable industrial transformation. Consequently, this study affirms that a firm's ENVP is the result of complex, interrelated factors, where managerial intent, knowledge infrastructure, operational systems, and external policies converge. These findings not only validate existing theoretical models but also open up new avenues for empirical and conceptual exploration within the evolving field of sustainable operations management in emerging economies.

6. CONCLUSION

This study provides compelling evidence that strategic deployment of EMPs and RENSC systems significantly enhances ENVP in manufacturing firms. EMPs and RENSC function as both operational tools and dynamic capabilities, enabling firms to reduce emissions, optimize energy use, and comply with evolving environmental regulations. Government incentives serve as critical institutional mechanisms that strengthen these internal strategies, thereby promoting greater environmental accountability and competitiveness. By integrating RBV, NRBV, and DCT, the study constructs a nuanced framework that captures how internal competencies, operational infrastructure, and external policy support interact to drive sustainable outcomes. The findings hold particular relevance for emerging economies like Oman, where sustainability agendas are gaining momentum but face structural and institutional challenges.

6.1. Theoretical Implications

The theoretical contributions of this study are multidimensional and offer fresh perspectives to the ongoing discourse on sustainability and energy strategy in emerging economies. This research holds academic significance as it empirically examines the synergistic influence of EMPs, RENSC, and GI on ENVP within the manufacturing sector in Oman. By integrating and extending the RBV, the NRBV, and DCT, this study enhances our understanding of how firms can build, adapt, and reconfigure their sustainability-related competencies in the face of evolving institutional and environmental conditions. First, this study contributes to the RBV by highlighting how EMPs function as strategic, internal capabilities that are valuable, rare, inimitable, and non-substitutable characteristics central to achieving a sustained competitive advantage (Barney, 2001). EMPs such as energy awareness, knowledge, and auditing are shown to be more than operational routines; they constitute embedded resources that shape the firm's capacity to enhance environmental outcomes. The empirical confirmation of their positive influence on ENVP validates the theoretical assertion that sustainability-oriented knowledge assets can serve as core competencies in industrial firms (Al-Madani et al., 2024; Fernando et al., 2018). Second, building upon Hart's (1995) NRBV, this study extends theoretical boundaries by illustrating how RENSC components, such as waste-to-energy systems, renewable integration, and decentralized energy distribution, represent environmental capabilities that support both operational efficiency and ecological stewardship. The NRBV perspective emphasizes that these green capabilities must proactively respond to environmental pressures rather than passively conform to regulatory demands. In this light, the integration of RENSC is conceptualized not just as a technological upgrade but as a capability for sustainable development that aligns environmental responsibility with competitive strategy (Al-Sheyadi et al., 2019; Gawusu et al., 2022).

Third, and most critically, the incorporation of the DCT Teece et al. (1997) offers an enriched explanatory lens for understanding how firms in rapidly evolving contexts like Oman adapt their resources and systems to sustainability imperatives. EMPs are interpreted not merely as static competencies, but as dynamic capabilities that allow organizations to sense opportunities (e.g., emerging green regulations), seize them (e.g., invest in solar or bioenergy infrastructure), and transform their energy configurations accordingly. This reconfiguration process is essential in economies where energy policies, technology standards, and stakeholder expectations are all in flux. Thus, the findings contribute to DCT by empirically demonstrating how internal routines and external stimuli (such as GOVI) interact to support continuous adaptation and strategic renewal in sustainability contexts (Labaran and Masood, 2023; Yavari and Bohreghi, 2025). Furthermore, this study repositions government incentives not as passive environmental context variables, as they are often treated in sustainability research, but as moderating institutional enablers. By confirming the interactive effect of GOVI on the EMPs–ENVP and RENSC–ENVP relationships, the study brings new depth to institutional interpretations of RBV and DCT. In line with recent arguments by Zhang and Huang (2024) the results suggest that dynamic capability deployment is more likely to occur when firms perceive government policy as supportive, predictable, and aligned with their strategic goals. This provides a compelling extension of DCT in particular, highlighting how policy contexts shape not only the opportunity space for capability development but also its effectiveness in achieving desired outcomes.

Additionally, this study adds contextual and theoretical nuance to the relatively underexplored sustainability dynamics of the Middle East and North Africa (MENA) region. While past studies have focused on Southeast Asia and Latin America, there has been limited theoretical application of integrated sustainability models in MENA economies. By situating the research in Oman, a country undergoing rapid energy policy transformation under Vision 2040, the study contributes to location-specific theorizing and opens new lines of inquiry for future comparative research. In sum, this research advances theoretical frameworks in several key ways: (1) by reconceptualizing EMPs as dynamic and strategic resources in line with RBV and DCT; (2) by positioning RENSC as a source of environmental capabilities and a vehicle for NRBV-aligned competitive advantage; (3) by empirically validating the enabling role of government incentives as dynamic catalysts for capability activation and performance realization; and (4) by contextualizing these insights within the institutional and economic realities of Oman, offering a foundation for theory-building in underrepresented regions.

6.2. Practical Implications

The findings offer valuable practical insights for managers, policymakers, and sustainability experts in the manufacturing sector, especially in emerging markets like Oman. By empirically examining the role of EMPs, (RENSC, and GI in enhancing environmental performance, this research offers actionable insights into the operationalization of sustainability in resource-constrained settings. First, the findings indicate that manufacturing managers should invest dedicated time and strategic resources into developing structured energy management programs that encompass energy awareness, knowledge development, and systematic auditing. These EMPs are not merely technical tools but are foundational elements of sustainability-oriented corporate culture. As Al-Madani et al. (2024) emphasize, EMPs should be integrated into core business processes to foster continuous monitoring, efficient resource use, and environmental accountability. For firms in Oman, where energy costs are increasingly volatile and regulatory pressures are rising, proactive energy management can improve not only environmental outcomes but also cost-efficiency and stakeholder trust. Second, the evidence underscores the critical role of the RENSC as a transformative infrastructure that allows firms to realign production processes with green energy objectives. Managers must recognize that the scope of environmental responsibility extends beyond the firm's immediate boundaries. In alignment with the observations of Karmaker et al. (2023), firms are responsible for the environmental performance of their supply chains, including supplier energy practices, waste management, and post-consumption product impact. During periods of disruption, such as the COVID-19 pandemic or geopolitical instability, managers must be prepared to answer key stakeholder questions: Are our products and processes safe and eco-friendly? How is energy sourced, distributed, and reused across the value chain? What environmental risks exist, and how are they mitigated? Addressing these questions not only supports compliance but also enhances customer satisfaction, regulatory alignment, and brand reputation. Third, government incentives were shown to play a catalytic role in enabling the effective implementation of energy strategies. Public policy actors should consider these findings as evidence to design more targeted and performance-based incentive schemes, such as green energy subsidies, low-interest financing for renewable installations, and recognition-based awards. From a managerial perspective, firms must remain vigilant in identifying and leveraging available government programs. As supported by Zhang and Huang (2024) GOVI mechanisms often provide the financial stability required to scale green innovations, particularly in developing markets where investment risks are typically high. Fourth, consistent with the dynamic capability perspective, firms must treat EMPs and RENSC not as static installations but as evolving competencies. Managers should actively encourage learning, experimentation, and feedback loops to refine their sustainability strategies over time. This includes continuous training, performance benchmarking, and stakeholder engagement to ensure the energy systems remain responsive to changing market, environmental, and technological conditions.

Finally, this study provides valuable guidance for crisis preparedness in energy and sustainability management. Echoing the observations of Mohamed Nazief Haggag Kotb Kholaif et al. (2022) future disruptions, be they pandemics, wars, or climate-related disasters, will require manufacturing firms to operate with resilience, agility, and data-driven insight. The deployment of EMPs and RENSC, supported by flexible GOVI structures, offers a practical pathway to mitigate environmental risks while maintaining business continuity. Moreover, as the geopolitical and ecological landscape continues to evolve, the lessons from this study serve as a strategic roadmap for firms seeking to future-proof their sustainability efforts. Hence, managers in the manufacturing sector, especially in countries undergoing energy transition, must move beyond compliance-driven environmental practices to embrace a strategic, system-wide approach. By aligning internal capabilities (EMPs), supply chain redesign (RENSC), and external incentives (GOVI), firms can realize meaningful improvements in environmental performance while contributing to national and global sustainability agendas.

6.3. Limitations and the Way Forward

Despite offering important theoretical and practical insights, this study is not without its limitations. A primary limitation lies in its geographical and sectoral scope. The research was conducted solely within the manufacturing sector in Oman, which, while strategically significant to the country's economic transformation goals, may not reflect the diversity of sustainability challenges and responses found in other sectors or national contexts. The concentration of the sample in a single country and industry limits the generalizability of the findings. As in similar studies conducted, broader cross-industry and cross-country sampling would enhance external validity. Future research should consider expanding the investigation to other sectors such as logistics, construction, and services, which also grapple with energy management and sustainability transitions, but under distinct institutional and operational constraints.

Second, this study relied entirely on self-reported data, which, while common in organizational and sustainability research, carries inherent risks of bias. Respondents may have over- or under-reported their engagement with energy management practices or the influence of government incentives due to social desirability or perceptual limitations. This subjectivity may affect the precision of the measured relationships. Future research should aim to complement self-reported data with more objective metrics, such as energy consumption logs, emissions records, or third-party audit reports, to triangulate findings and ensure measurement robustness (Podsakoff et al., 2003). Third, the study employed a cross-sectional design, capturing firm behavior and outcomes at a single point in time. While this approach provides useful insights into current practices and relationships, it does not account for the temporal evolution of sustainability capabilities, policy shifts, or changes in firm strategies. It is suggested that, a longitudinal design would allow researchers to examine how the interaction between energy management practices, RENSC, and external enablers like government incentives evolves over time, especially in response to environmental disruptions or policy reforms. For instance, understanding whether short-term improvements in environmental performance led to sustained behavioral and structural change would offer meaningful implications for theory and practice.

Fourth, while this study focused on government incentives as an institutional moderator, other contextual or organizational variables may influence the effectiveness of renewable energy SCM. Variables such as corporate social responsibility (CSR), digital infrastructure maturity, environmental regulation compliance pressure, and technological readiness (e.g., use of IoT or AI) could offer complementary or competing influences on ecological performance. Future research should examine these variables as potential moderators or mediators to build a more comprehensive model of sustainability strategy in manufacturing. In particular, the integration of digital transformation enablers, such as big data analytics (BDA), artificial intelligence (AI), or blockchain, could offer richer insights into how firms optimize their renewable energy systems under varying institutional and technological conditions. Lastly, while this study provides valuable insights into how energy management practices, RENSC, and government incentives influence environmental performance in Oman's manufacturing sector, its limitations highlight important directions for future research. Expanding geographic scope, incorporating objective data, employing longitudinal designs, and testing additional variables will further enrich our understanding of how firms navigate the intersection of sustainability, policy, and technology in a rapidly evolving global context.

REFERENCES

Abdelaziz, E.A., Saidur, R., Mekhilef, S. (2011), A review on energy saving strategies in industrial sector. Renewable and Sustainable Energy Reviews, 15(1), 150-168.

Afum, E., Osei-Ahenkan, V.Y., Agyabeng-Mensah, Y., Amponsah Owusu, J., Kusi, L.Y., Ankomah, J. (2020), Green manufacturing practices and sustainable performance among Ghanaian manufacturing SMEs: The explanatory link of green supply chain integration. Management of Environmental Quality: An International Journal, 31(6), 1457-1475.

Aktar, M.A., Dhahi, A.K.A., Abdullahi, U. (2024), Advancing sustainable development through the lens of energy efficiency : A systematic literature review. International Journal of Energy Economics and Policy, 14(5), 168-180.

Al-Madani, M.H.M., Fernando, Y., Iranmanesh, M., Lim, M.K., Tseng, M.L. (2024), Renewable energy supply chain in Malaysia: Fostering energy management practices and ecological performance. Renewable Energy, 226, 120441.

Al-Sarihi, A., Cherni, J.A. (2018), Assessing strengths and weaknesses of renewable energy initiatives in Oman: an analysis with strategic niche management. Energy Transitions, 2(1-2), 15-29.

Al-Sarihi, A., Mason, M. (2020), Challenges and opportunities for climate policy integration in oil-producing countries: The case of the UAE and Oman. Climate Policy, 20(10), 1226-1241.

Al-Sheyadi, A., Muyldermans, L., Kauppi, K. (2019), The complementarity of green supply chain management practices and the impact on environmental performance. Journal of Environmental Management, 242, 186-198.

Amiri-Pebdani, S., Alinaghian, M., Safarzadeh, S. (2022), Time-of-use pricing in an energy sustainable supply chain with government interventions: A game theory approach. Energy, 255, 124380.

Anderson, J.C., Gerbing, D.W. (1988), Structural equation modeling in practice: A review and recommended two-step approach. Psychological Bulletin, 103(3), 411.

Barney, J.B. (2001), Is the resource-based “view” a useful perspective for strategic management research? Yes. Academy of Management Review, 26(1), 41-56.

Becker, J.M., Cheah, J.H., Gholamzade, R., Ringle, C.M., Sarstedt, M. (2023), PLS-SEM’s most wanted guidance. International Journal of Contemporary Hospitality Management, 35(1), 321-346.

Benitez, J., Henseler, J., Castillo, A., Schuberth, F. (2020), How to perform and report an impactful analysis using partial least squares: Guidelines for confirmatory and explanatory IS research. Information and Management, 57(2), 103168.

Boons, F., Wagner, M. (2009), Assessing the relationship between economic and ecological performance: Distinguishing system levels and the role of innovation. Ecological Economics, 68(7), 1908-1914.

Cain, M.K., Zhang, Z., Yuan, K.H. (2017), Univariate and multivariate skewness and kurtosis for measuring nonnormality: Prevalence, influence and estimation. Behavior Research Methods, 49(5), 1716-1735.

Cerchione, R., Esposito, E. (2016), A systematic review of supply chain knowledge management research: State of the art and research opportunities. International Journal of Production Economics, 182, 276-292.

Dawson, J.F. (2014), Moderation in Management Research: What, Why, When, and How. Journal of Business and Psychology, 29(1), 1-19.

Dorian, J.P., Shealy, M.T., Simberk, D.R. (2020), The global energy transition: Where do we go from here. IAEE Energy Forum/Second Quarter, 2020, 11-18.

Fernando, Y., Bee, P.S., Jabbour, C.J.C., Thomé, A.M.T. (2018), Understanding the effects of energy management practices on renewable energy supply chains: Implications for energy policy in emerging economies. Energy Policy, 118, 418-428.

Fernando, Y., Tseng, M.L., Aziz, N., Ikhsan, R.B., Wahyuni-Td, I.S. (2022), Waste-to-energy supply chain management on circular economy capability: An empirical study. Sustainable Production and Consumption, 31, 26-38.

Fontes, C.H.O., Freires, F.G.M., Freires, F.G. (2018), Sustainable and renewable energy supply chain: A system dynamics overview. Renewable and Sustainable Energy Reviews, 82, 247-259.

Franke, G., Sarstedt, M. (2019), Heuristics versus statistics in discriminant validity testing: A comparison of four procedures. Internet Research, 29(3), 430-447.

Gaitán, J.J., Bran, D., Oliva, G., Ciari, G., Nakamatsu, V., Salomone, J., Ferrante, D., Buono, G., Massara, V., Humano, G., Celdrán, D., Opazo, W., Maestre, F.T. (2013), Evaluating the performance of multiple remote sensing indices to predict the spatial variability of ecosystem structure and functioning in Patagonian steppes. Ecological Indicators, 34, 181-191.

Ganesh, A.H., Xu, B. (2022), A review of reinforcement learning based energy management systems for electrified powertrains: Progress, challenge, and potential solution. Renewable and Sustainable Energy Reviews, 154, 111833.

Gawusu, S., Zhang, X., Jamatutu, S.A., Ahmed, A., Amadu, A.A., Djam Miensah, E. (2022), The dynamics of green supply chain management within the framework of renewable energy. International Journal of Energy Research, 46(2), 684-711.

Gillingham, K., Sweeney, J. (2012), Barriers to implementing low-carbon technologies. Climate Change Economics, 3(04), 1250019.

Gogoi, A., Ahirwal, J., Sahoo, U.K. (2022), Evaluation of ecosystem carbon storage in major forest types of Eastern Himalaya: Implications for carbon sink management. Journal of Environmental Management, 302, 113972.

Govindan, K., Soleimani, H., Kannan, D. (2015), Reverse logistics and closed-loop supply chain: A comprehensive review to explore the future. European Journal of Operational Research, 240(3), 603-626.

Gunarathne, N., Lee, K.H. (2021), The link between corporate energy management and environmental strategy implementation: Efficiency, sufficiency and consistency strategy perspectives. Journal of Cleaner Production, 293, 126082.

Hahn, E.D., Ang, S.H. (2017), From the editors: New directions in the reporting of statistical results in the Journal of World Business. Journal of World Business, 52(2), 125-126.

Hair, J. Jr., Hair, J.F. Jr., Hult, G.T.M., Ringle, C.M., Sarstedt, M. (2022), A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM). United States: Sage Publications.

Hair, J.F., Astrachan, C.B., Moisescu, O.I., Radomir, L., Sarstedt, M., Vaithilingam, S., Ringle, C.M. (2021), Executing and interpreting applications of PLS-SEM: Updates for family business researchers. Journal of Family Business Strategy, 12(3), 100392.

Hart, S.L. (1995), A natural-resource-based view of the firm. Academy of Management Review, 20(4), 986-1014.

Hart, S.L., Dowell, G. (2011), A natural-resource-based view of the firm: Fifteen years after. Journal of Management, 37(5), 1464-1479.

Hassanin, I., Knez, M. (2022), Managing supply chain activities in the field of energy production focusing on renewables. Sustainability, 14(12), 7290.

Henseler, J., Ringle, C.M., Sarstedt, M. (2015), A new criterion for assessing discriminant validity in variance-based structural equation modeling. Journal of the Academy of Marketing Science, 43, 115-135.

Hmouda, A.M.O., Orzes, G., Sauer, P.C. (2024), Sustainable supply chain management in energy production: A literature review. Renewable and Sustainable Energy Reviews, 191, 114085.

Karmaker, C.L., Al Aziz, R., Palit, T., Bari, A.M. (2023), Analyzing supply chain risk factors in the small and medium enterprises under fuzzy environment: Implications towards sustainability for emerging economies. Sustainable Technology and Entrepreneurship, 2(1), 100032.

Khattak, M.S., Shah, S.Z.A. (2021), Entrepreneurial orientation and the efficiency of SMEs: The role of government financial incentives in an emerging industry. Journal of Public Affairs, 21(3), 1-15.

Khattak, S.I., Khan, M.K., Sun, T., Khan, U., Wang, X., Niu, Y. (2022), Government innovation support for green development efficiency in China: A regional analysis of key factors based on the dynamic GMM model. Frontiers in Environmental Science, 10, 1-14.

Kim, J.E. (2019), Sustainable energy transition in developing countries: The role of energy aid donors. Climate Policy, 19(1), 1-16.

Klemeš, J.J., Varbanov, P.S., Ocłoń, P., Chin, H.H. (2019), Towards efficient and clean process integration: Utilisation of renewable resources and energy-saving technologies. Energies, 12(21), 4092.

Kock, N. (2015), Common method bias in PLS-SEM: A full collinearity assessment approach. International Journal of E-Collaboration, 11(4), 1-10.

Kock, N., Lynn, G.S. (2012), Lateral collinearity and misleading results in variance-based SEM: An illustration and recommendations. Journal of the Association for Information Systems, 13(7), 546-580.

Kongbuamai, N., Bui, Q., Nimsai, S. (2021), The effects of renewable and nonrenewable energy consumption on the ecological footprint: The role of environmental policy in BRICS countries. Environmental Science and Pollution Research, 28(22), 27885-27899.

Květoň, V., Horák, P. (2018), The effect of public R and D subsidies on firms' competitiveness: Regional and sectoral specifics in emerging innovation systems. Applied Geography, 94, 119-129.

Labaran, M.J., Masood, T. (2023), Industry 4.0 driven green supply chain management in renewable energy sector: A critical systematic literature review. Energies, 16(19), 6977.

Laosirihongthong, T., Adebanjo, D., Choon Tan, K. (2013), Green supply chain management practices and performance. Industrial Management & Data Systems, 113(8), 1088-1109.

Lin, Y., Mahmood, M.A., Meng, W., Ali, Q. (2024), Green economy transition in Asia Pacific: A holistic assessment of renewable energy production. Journal of Cleaner Production, 437, 140648.

Little, R.J.A. (1988), A test of missing completely at random for multivariate data with missing values. Journal of the American Statistical Association, 83(404), 1198-1202.

Losada-Agudelo, M., Souyris, S. (2024), Sustainable operations management in the energy sector: A comprehensive review of the literature from 2000 to 2024. Sustainability, 16(18), 7999.

Maghyereh, A., Boulanouar, Z., Essid, L. (2025), The dynamics of green innovation and environmental policy stringency in energy transition investments. Journal of Cleaner Production, 487, 144649.

McDougall, N., Wagner, B., MacBryde, J. (2022), Leveraging competitiveness from sustainable operations: frameworks to understand the dynamic capabilities needed to realise NRBV supply chain strategies. Supply Chain Management, 27(1), 12-29.

Mekhilef, S., Saidur, R., Safari, A. (2011), A review on solar energy use in industries. Renewable and Sustainable Energy Reviews, 15(4), 1777-1790.

Mohamed Nazief Haggag Kotb Kholaif, M., Xiao, M., Tang, X. (2022), Covid-19's fear-uncertainty effect on renewable energy supply chain management and ecological sustainability performance; the moderate effect of big-data analytics. Sustainable Energy Technologies and Assessments, 53(PC), 102622.

Mohanty, M. (2012), New renewable energy sources, green energy development and climate change: Implications to Pacific Island countries. Management of Environmental Quality: An International Journal, 23(3), 264-274.

Moktadir, M.A., Rahman, M.M. (2022), Energy production from leather solid wastes by anaerobic digestion: A critical review. Renewable and Sustainable Energy Reviews, 161, 112378.

Monasterolo, I., Raberto, M. (2018), The EIRIN flow-of-funds behavioural model of green fiscal policies and green sovereign bonds. Ecological Economics, 144, 228-243.

Morrar, R., Khaldi, Y.M., Hinn, H.I. (2025), Gradual Transition to renewable energy in palestine: The enabling environment to attract local and international investments. Studies in Systems, Decision and Control, 568, 1077-1090.

National Centre for Statistics and Information. (2023), Population. Data Portal - Oman. Available from: https://data.gov.om/OMPOP2016/population [Last accessed on 2025 Apr 19].

Nchake, M.A. (2025), Green Transition, Trade Policy and Sustainable Development: An African Perspective. Globalization: Past, Present and Future Perspectives. New York: Nova Science Publishers. p125-148.

Ning, J., Liu, B., Xu, Y., Yu, L. (2025), Does green supply chain management improve corporate sustainability performance? Evidence from China. Environmental Impact Assessment Review, 112, 107828.

Olatomiwa, L., Mekhilef, S., Ismail, M.S., Moghavvemi, M. (2016), Energy management strategies in hybrid renewable energy systems: A review. Renewable and Sustainable Energy Reviews, 62, 821-835.

Patel, A.R., Vyas, D.R., Markana, A., Jayaraman, R. (2022), A conceptual model for integrating sustainable supply chain, electric vehicles, and renewable energy sources. Sustainability (Switzerland), 14(21), 1-14.

Podsakoff, P.M., MacKenzie, S.B., Lee, J.Y., Podsakoff, N.P. (2003), Common method biases in behavioral research: A critical review of the literature and recommended remedies. Journal of Applied Psychology, 88(5), 879.

Preacher, K.J., Hayes, A.F. (2004), SPSS and SAS procedures for estimating indirect effects in simple mediation models. Behavior Research Methods, Instruments, and Computers, 36, 717-731.

Rahman, M.S., Noman, A.H.M., Shahari, F., Aslam, M., Gee, C.S., Isa, C.R., Pervin, S. (2016), Efficient energy consumption in industrial sectors and its effect on environment: A comparative analysis between G8 and Southeast Asian emerging economies. Energy, 97, 82-89.

Ramayah, T., Cheah, J., Chuah, F., Ting, H., Memon, M.A. (2018), Partial least squares structural equation modeling (PLS-SEM) using smartPLS 3.0. An Updated Guide and Practical Guide to Statistical Analysis.

Rauter, R., Jonker, J., Baumgartner, R.J. (2017), Going one's own way: Drivers in developing business models for sustainability. Journal of Cleaner Production, 140, 144-154.

Rothenberg, S., Schenck, B., Maxwell, J. (2005), Lessons from benchmarking environmental performance at automobile assembly plants. Benchmarking: An International Journal, 12(1), 5-15.

Sadiq, M., Nawaz, M.A., Sharif, A., Hanif, S. (2024), Bridging green supply chain practices and environmental performance in Chinese semiconductor sector: With the role of energy efficiency and green HRM. International Journal of Production Economics, 277, 109381.

Schulze, M., Nehler, H., Ottosson, M., Thollander, P. (2016), Energy management in industry - A systematic review of previous findings and an integrative conceptual framework. Journal of Cleaner Production, 112, 3692-3708.

Shmueli, G., Sarstedt, M., Hair, J.F., Cheah, J.H., Ting, H., Vaithilingam, S., Ringle, C.M. (2019), Predictive model assessment in PLS-SEM: Guidelines for using PLSpredict. European Journal of Marketing, 53(11), 2322-2347.

Singh, N., Jain, S., Sharma, P. (2016), Environmental benchmarking practices in Indian industries: Evidences from an empirical study. Benchmarking, 23(5), 1132-1146.

Teece, D.J., Pisano, G., Shuen, A. (1997), Dynamic capabilities and strategic management. Strategic Management Journal, 18(7), 509-533.

Teece, D.J., Pisano, G., Shuen, A. (2009), Dynamic capabilities and strategic management. Knowledge and Strategy, 18(7), 77-116.

Thollander, P., Palm, J. (2013), Improving Energy Efficiency in Industrial Energy Systems: An Interdisciplinary Perspective on Barriers, Energy Audits, Energy Management, Policies, and Programs. Vol. 9781447141. Germany: Springer Science + Business Media.

Vazifeh, Z., Mafakheri, F., An, C. (2023), Coordination of bioenergy supply chains under government incentive policies: A game-theoretic analysis. Clean Technologies and Environmental Policy, 25(7), 2185-2201.

Wang, S., Cheah, J.H., Wong, C.Y., Ramayah, T. (2023), Progress in partial least squares structural equation modeling use in logistics and supply chain management in the last decade: A structured literature review. International Journal of Physical Distribution and Logistics Management, 54(7-8), 673-704.

Yavari, M., Bohreghi, I.M. (2025), Developing a green-resilient power network and supply chain: Integrating renewable and traditional energy sources in the face of disruptions. Applied Energy, 377(Part C), 124654.

Zhang, H., Huang, Q. (2024), Innovations in supply chain management for sustainable energy transition: Lessons from leading enterprises. Economic Change and Restructuring, 57(3), 111.