Scientific Research Publishing

Journal of Power and Energy Engineering, 2026, 14(5), 21-37
https://www.scirp.org/journal/jpee
ISSN Online: 2327-5901
ISSN Print: 2327-588X

The Effect of Green Supply Chain on the Omani Energy Efficiency Program: Evidence from the Conformity Assessment Perspective

Salah Abdullah Al Khusaibi

Developing Quality and Conformity, Directorate General for Standards and Metrology, Ministry of Commerce, Industry, and Investment Promotion, Muscat, Sultanate of Oman
Email: s.alkhusaibi66@gmail.com

How to cite this paper: Al Khusaibi, S.A. (2026) The Effect of Green Supply Chain on the Omani Energy Efficiency Program: Evidence from the Conformity Assessment Perspective. *Journal of Power and Energy Engineering*, **14**, 21-37.
https://doi.org/10.4236/jpee.2026.145002

Received: March 31, 2026
Accepted: May 26, 2026
Published: May 29, 2026

Abstract

This study examined the factors influencing the Omani Energy Efficiency Rating (EER) Program, with particular emphasis on the role of green supply chain practices. Structural Equation Modeling was employed using AMOS software to test the proposed research hypotheses and assess the impact of green supply chain dimensions on program effectiveness. A semi-quantitative, cross-sectional design was adopted. Data were collected from 19 employees representing 10 economic operators involved in the (EER) program. The study targeted senior and mid-level managers due to their role in strategic planning and policy development. Data were gathered through a self-administered electronic questionnaire and analyzed using AMOS software. The findings show that green supply chain practices are widely adopted and strongly interconnected; however, their effects on EER vary. Green Purchasing has a significant positive impact on EER, while Eco-design, Green Distribution, and Green Reverse Logistics exhibit weak or negative effects, and Green Manufacturing shows a negligible relationship. Overall, the model explains limited variance in EER, indicating the influence of additional factors. The study recommends strengthening and expanding the Energy Efficiency Rating Program through enhanced regulatory frameworks, broader product coverage, and the promotion of sustainable practices. These measures support national energy objectives and contribute to achieving Oman Vision 2040, the Paris Agreement, and the Sustainable Development Goals (SDGs).

Keywords

Energy Efficiency Rating (EER), Green Supply Chain, Eco-Design, Green Distribution, Green Purchasing, Green Manufacturing, and Green Reverse Logistics, Conformity Assessment and Standards

1. Introduction

The globalization of trade has increased firms' dependence on international standards and conformity assessments, fostering harmonized linkages within supply chains and enhancing access to international markets [1]. The significance of standards and conformity assessment is evident in numerous scholarly publications and special issues, including a dedicated issue on meta-standards in IJPE [2] and on standards and innovation [3].

Conformity assessment considers the rapidly growing global marketplace to facilitate prompt adaptation and responses to market trends. Corporate responsibility and sustainability are increasingly crucial factors in organizational development, influencing both management researchers and practitioners. Over the past decade, manufacturers have faced heightened pressure to implement environmentally sustainable practices and offer eco-friendly products [4]. They have acknowledged the important role of their supply chain partners in environmental management. Consequently, numerous sectors are now seeking innovative solutions to environmental challenges from their suppliers and consumers. This recognition of green supply chain management (GSCM) prompted an evaluation of environmental impacts on effective supply chain operations.

In response to the increasing global demand for "green" products, the Directorate General for Standards and Metrology (DGSM) in the Sultanate of Oman has initiated the implementation of the Energy Efficiency Program as part of the Oman Conformity Scheme. This initiative aims to improve the energy efficiency of products in the Omani market, reduce the overall energy consumption, and ensure compliance with energy efficiency regulations. Through this initiative, the DGSM aims to promote sustainable practices, contribute to environmental conservation, and align with Oman's commitment to sustainability and green transformation as outlined in Oman Vision 2040.

Notwithstanding the increasing importance of energy efficiency in Oman's shift toward a green economy, there remains a notable research gap in the field of standardization, particularly concerning the integration of energy efficiency ratings within operational management practices. The existing research primarily focus on specific management system standards, such as ISO 9001 and ISO 14001, overlooking the wider ramifications of standards and conformity assessments.

[5] [6] argues that a mandated energy efficiency label effectively alters consumer consumption behaviors and encourages the purchase of energy-saving appliances. Nevertheless, limited research addresses the influence of energy efficiency labels on consumer purchase behavior.

This paper seeks to address this gap by exploring the effect of green supply chain on the Energy Efficiency Program and its potential to drive Oman's green transformation.

2. Literature Review

2.1. Conformity Assessment

Conformity assessment is defined by ISO/IEC 17000:2020 as "a demonstration that specified requirements related to a product, process, system, person, or body are fulfilled" [7]. This process encompasses testing, inspection, and certification, which are essential for verifying that products and services adhere to regulatory and customer standards. Conformity assessment is crucial for establishing consumer trust and promoting international trade by confirming compliance with established standards (ISO, 2020). Several research studies highlight the importance of conformity assessment in diverse sectors. [8] state that conformity assessment is crucial in ensuring the safety and safety and reliability of products and services, thereby enhancing the reliability of operations and fostering mutual recognition. The National Institute of Standards and Technology (NIST) points out that conformity assessment is essential for the efficient functioning of markets, as it fosters trust between buyers and sellers regarding the products exchanged [9]. Conformity assessment is a fundamental element in the transformative era of Industry 4.0, where technological developments are reshaping manufacturing and industrial landscapes, ensuring quality, compliance, and supporting innovation [10].

Few studies in the Gulf region have thoroughly examined conformity assessment, despite its crucial importance in improving product quality, ensuring consumer safety, and facilitating intra-GCC trade [11]. indicate that the GSO has made significant progress by launching the Regional Conformity Assessment Scheme project in November 2005. This initiative by GSO seeks to advance the objectives of the GCC through the coordination, integration, and establishment of standardization frameworks and quality infrastructure within the member states. Additionally, the Saudi Standards, Metrology and Quality Organization (SASO) establishes Saudi standards in all required fields such as goods, products and services, and measurement and implements procedures for conformity assessment and certification. In the Sultanate of Oman, the MoCIIP established the Technical Regulation of the Conformity Scheme under Ministerial Decision No. 190/2021 to provide a uniform national framework for guaranteeing that products fulfill national obligations. The legislation defines economic operators' obligations, describes conformity assessment procedures, and establishes standards for the DGSM's notification and supervision of CABs. It also specifies the legal basis for granting conformity certificates, conducting market surveillance, and enforcing compliance measures to ensure consumer safety and product quality.

The rule was published in Official Gazette No. 1419 on 5 December 2021 and entered into force six months later, establishing the basis of the Omani Conformity Scheme and its subsequent progressive implementation across regulated product categories [12].

2.2. Green Supply Chain

Supply chain management (SCM) is the process of coordinating and managing the intricate network of relationships designed to supply a suitable product to the end-user or consumer [13]. Green SCM signifies the integration of environmental factors into SCM (SCM) [14]. GSCM involves the implementation of a proactive strategy aimed at enhancing the environmental performance of its processes and products to comply with environmental regulatory requirements [15]. [16] examine the role of standards and certifications as critical tools for assessing and enhancing environmental and sustainable supply chain performance. [17] investigate the motivations and advantages of adopting certification schemes in apparel supply chains, emphasizing the potential of these certifications to improve sustainability practices in the industry. The study by [18] analyzes the coordination between tradable white certificate (TWC) and tradable green certificate (TGC) markets in energy supply chains, highlighting the effects of reward-penalty mechanisms on sustainable energy generation. [19] examine how institutional forces, including legislation and customer expectations, promote the implementation of GSCM practices and green certifications. [19] argue that leadership and senior management support are crucial for the effective implementation of GSCM and for guaranteeing compliance via conformity assessment.

[20] analyze the influence of GSCM on organizational performance, positing that environmental certification significantly enhances both ecological and economic outcomes. [21] stated that quality management serves as a precursor to maturity in environmental management, which impacts the implementation of GSCM practices and overall performance. [22] provide an extensive overview of the literature on GSCM, highlighting the incorporation of environmental criteria into supply chain practices and the significance of certification for compliance assurance.

[23] investigate the correlation between GSCM approaches and environmental performance within the electronics sector in Taiwan region, demonstrating that con-formity assessment via certifications aids companies in adhering to environmen-tal standards. [24] examine the impact of environmental regulations on European companies, suggesting that eco-labeling and other conformity assessment meth-ods are crucial for compliance.

[25] defined green practices within the supply chain into two categories of environmental activities: environmental cooperation and environmental monitoring. [21] defined external GSCM practices as "Cooperation with Customers" (CC) and "Green Purchasing" (GP). [26] examined green purchasing practices, eco-design practices, reverse logistics practices, and the impact of legalization and regulation. Green supply chain practices are assessed through three variables: green transportation, green distribution, and green purchasing [27]. [14] identify GSCM practices as encompassing green procurement, green manufacturing, green distribution, and green logistics. Consensus was reached with the findings of [28] as well as [13]. Green supply chain practices were evaluated using five variables: green manufacturing, green purchasing, green information systems, information systems cooperation with customers, and eco-design [29]. Accordingly, this research relies on the dimensions of green practices of the supply chain, represented in eco-design, green distribution, green purchasing, green manufacturing, and

green reverse logistics.

2.3. Energy Efficiency Rating (EER)

The EER program is part of the Oman Conformity Scheme implemented by the Directorate General for Standards and Metrology (DGSM). It aims to reduce overall energy consumption and ensure products in the Omani market comply with established energy efficiency regulations. Standards are often established via law or regulatory frameworks and are frequently revised to incorporate technological advancements and enhancements in energy efficiency. Energy-efficient appliances are essential for decreasing household energy usage and fostering sustainable living practices. The importance of these appliances is paramount as the globe faces the challenges of climate change and energy sustainability [30]. The energy efficiency label offers consumers environmental and energy information regarding home appliances, facilitating the comparison and selection of more energy-efficient items. The label is generally represented through a numerical value or letter grade, with elevated ratings indicating superior energy performance and lower energy use. Energy-efficient appliances frequently employ sophisticated technology, such variable speed compressors in freezers and heat pumps in water heaters, to attain elevated efficiency levels [31]-[32]. The energy efficiency label is a widely utilized tool for lowering the energy consumption of household appliances in several places globally [33].

Numerous studies point out the global significance of energy efficiency ratings. In the European Union, the Energy Labelling Scheme has facilitated a reduction in energy use by providing clear ratings for equipment such as refrigerators and washing machines (European Commission, 2020). Recent Eurobarometer studies indicate that the energy label is well recognized among citizens, with 93% of consumers acknowledging it and 75% utilizing it to guide their purchases (European Commission, 2020). The Energy Star program in the United States has substantially aided energy conservation by offering ratings for diverse products, such as appliances and electronics (U.S. Environmental Protection Agency, 2019).In 2018, ENERGY STAR certified products enabled consumers to conserve approximately 200 billion kilowatt-hours of power, circumvent $20 billion in energy expenses, and realize a reduction of 150 million metric tons of greenhouse gas emissions.

[34] investigated the characteristics of existing labels in European developed countries. [35] identified key elements and practices in implementing building energy codes in 22 countries. Mills and Schleich (2010) demonstrate that when customers are unaware of energy efficiency labels, significant discrepancies may arise in estimating the utilization rates of energy-saving equipment and their potential determinants. Weissman (2024) states that the U.S. Department of Energy's Appliance and Equipment Standards Program encompasses over 70 products, representing over 90% of residential energy use, 70% in commercial structures, and 30% in industrial sectors. These standards resulted in an expected sav-

ings of $105 billion for American consumers in 2024, with the average household saving approximately $576 compared to a scenario devoid of efficiency measures. [26] developed a hedonic pricing model for a metropolitan region in Atlanta, U.S., to elucidate the economic worth of energy-efficiency labels, revealing that homes with energy certificates commanded a sale price premium of 11.7%. [36] developed a systematic methodology for examining the variances between the projected and actual energy consumption of 21 faculty buildings at the University of Zaragoza campus. A study conducted in Germany investigated the impact of replacing old age refrigerators with energy-efficient models. The findings of the research indicated that homes that replaced their old refrigerators with energy-efficient models saved up to 50% on refrigeration energy costs. The analysis showed that households could save between €100 and €150 each year. The results further indicated that the newly developed energy-efficient refrigerators exhibited a payback period ranging from 3 to 5 years, positioning them as a financially viable option for households [37].

The European Parliament and Council's Directive 2009/125/EC created a common set of rules to set eco-design requirements for energy-related products, with the goal of making sure they are environmentally friendly throughout their entire lifecycle. As defined by Regulation (EU) 2017/1369, the energy label shall represent updated performance categories (A to G). The 2021 International Energy Conservation Code (IECC) requires builders to implement superior thermal insulation and improve window efficiency to significantly decrease energy usage in residential and commercial buildings. As reported by the GCC Standardization Organization (2021), an agreement was established on April 1, 2021, with the Ministry of Industry, Commerce, and Tourism of the Kingdom of Bahrain to facilitate services concerning the operation and advancement of the Bahraini Energy Efficiency Labeling System. The Emirates Authority for Standardization and Metrology (ESMA, 2022) indicates that the UAE has established compulsory energy efficiency labeling initiatives for household appliances, including air conditioners, refrigerators, and washing machines, aimed at fostering sustainable energy use and minimizing environmental effects. The Saudi Standards, Metrology and Quality Organization (SASO, 2023) mandates that the Energy Efficiency Label for electric dishwashers necessitate the registration of the requisite conformity certificate to facilitate the issuance of the shipment certificate via the SABER electronic platform.

The Directorate General for Standards and Metrology (DGSM) announced on June 8, 2023, that Phase 2 of the Omani Conformity Scheme, outlined in Royal Decree No. 190/2021, has commenced. This phase requires energy efficiency (EE) labelling for an expanded range of household products. The Guidance on Conformity Assessment Procedures (CAP) for the Oman Energy Efficiency Labelling Scheme (Directorate General for Standards and Metrology [DGSM], 2023) explains that the Energy Efficiency and Regulation (EER) program is based on several important factors, including the obligations of economic operators, energy labelling, safety and minimum energy performance requirements, the HAZM platform, market surveillance, mandatory products, and harmonized standards.

2.4. Energy Efficiency and Green Supply Chain

Energy efficiency is essential for reaching sustainability objectives by decreasing resource usage and lowering carbon emissions throughout the supply chain. Fernando *et al.* (2018) illustrated the effects of energy management methods on renewable energy supply chains. [38] emphasize that energy-efficient supply chains are crucial for achieving sustainability. Minimizing carbon emissions safeguards the environment and is essential for promoting environmental sustainability. [39] point out that including energy consumption into SCM can enhance energy efficiency in processes from a systemic perspective. [32] discovered that the digitization of supply chains plays a crucial role in enhancing corporate energy efficiency by leveraging green technology innovation. [40] emphasized that the green supply chain is increasingly recognized as a vital strategy for numerous industries and enterprises, as it fosters low energy consumption and mitigates environmental and air pollution. The ISO 50001:2018 standard serves as a globally acknowledged energy management system (EMS) designed to assist organizations across various sectors in enhancing energy efficiency through a Plan-Do-Check-Act (PDCA) continual improvement framework (International Organization for Standardization, 2018). [41] examine the essential function of energy efficiency in improving environmental performance in the context of GSCM, with a specific focus on the Chinese automobile industry. [42] emphasize that the adoption of energy-efficient practices in the supply chain of the manufacturing sector is crucial for attaining sustainability and enhancing energy performance. [38] highlight that green supply chain practices demonstrate a marked superiority over traditional models in their ability to decrease energy consumption and mitigate environmental damage. [43] discovered that energy efficiency labels in China significantly contribute to the promotion of technological innovation among manufacturers, thereby enhancing sustainable supply chain practices. Zu and Zeng (2020) illustrate that energy efficiency standards set by the government have a considerable impact on the decisions made by manufacturers and retailers, promoting investments in energy-saving measures throughout the supply chain. Based on the above discussion, the following research hypothesis is proposed:

Green supply chain practices have a significant impact on the Energy Efficiency Program. **Figure 1** illustrates the structure of the proposed research model and reflected the Main hypothesis.

3. Research Method

3.1. Population and Sample

Data related to the impact of the green supply chain on the EER program were collected from Ten Economical Operators in the Sultanate of Oman. This research targeted managers at the senior and middle levels, as they are responsible for

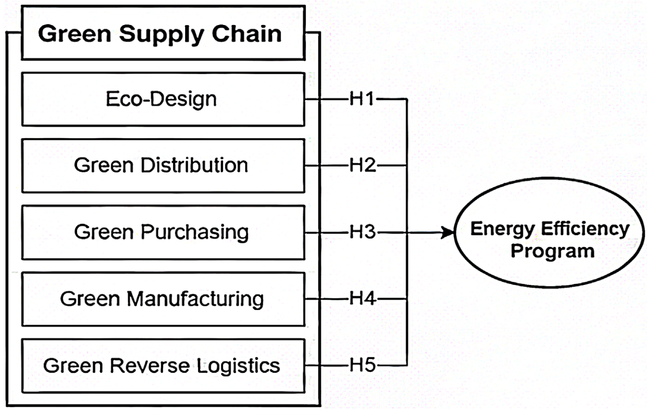

Figure 1. Research model.

formulating organizational strategies and determining corporate policies. Nineteen (19) managers were selected as a sample using purposive sampling. The research questionnaire was sent to them via email, and they were asked to return it within one week. Moreover, it was emphasized that the questionnaires would be treated with strict confidentiality. It was found that 68.4% of respondents were male, while 31.6% were female. In terms of age, the majority of respondents 47.4% fell within the category "25 - 34," followed by 36.8% in the category "35 - 44," and finally 15.8% of those in the category "45 and above.

3.2. Measures

According to the study aims, a model was developed that contains an independent variable, the GSC, and a dependent variable, the Energy Efficiency Program. To collect the data needed for the analysis, a self-administered questionnaire was created electronically using Google Forms. This survey's elements were initially prepared in English. This questionnaire included a section to determine the demographic characteristics of the research sample (gender, age, organization name, job title, and department), which were categorical variables, as well as two sections dedicated to the main research variables, with responses determined using a five-point Likert scale. Determined using a five-point Likert scale. Developed in English. The elements of this measure were adapted from the Guidance on Conformity Assessment Procedures (CAP) for the Oman Energy Efficiency Labelling Scheme issued by the Directorate General for Standards and Metrology (DGSM).

Green supply chain: This characteristic was measured using 22 items adopted from Khan *et al.* (2022). This scale was developed to examine respondents' impressions of economical operators implementing green supply chain approaches in the Sultanate of Oman. Developed in English. The green supply chain was examined as a second-order architecture subdivided into six first-order constructs. Four indicators are used to evaluate ecological design, for example: "The company strives to design products that can be recycled and recover their materials and components." Green distribution was measured using five items, for example: "The company uses recyclable cartons when distributing products in the market".

Green purchasing was measured using four items, for example:" The company focuses on environmental audit procedures to assess and manage supplier relationships". Green manufacturing was measured using four items, for example: "The company emphasizes an operational strategy that minimizes waste and optimizes resource investment". Green reverse logistics was measured using five items, for example: "The company follows a policy of collecting used products for recycling or proper disposal".

3.3. Validation

To ensure the accuracy, reliability, and credibility of the measurement instrument used in this study, a validation process was conducted prior to hypothesis testing. Validation is essential in empirical research to confirm that the data collection instrument adequately measures the intended constructs and produces consistent results. Accordingly, several statistical techniques were employed to assess the reliability and validity of the study variables. The following Table 1 showed the Cronbach's Alpha (α) results the measure the validation.

Table 1. Validation.

Construct	Cronbach's Alpha (α)
Eco-design	0.969
Green Manufacturing	0.933
Green Purchasing	0.835
Green Reverse Logistics	0.816
Energy Efficiency Rating (EER)	0.886
Green Distribution	0.769

The table results indicate the internal consistency reliability of the study constructs as measured by Cronbach's Alpha (α). All constructs demonstrate acceptable to excellent reliability, as Cronbach's Alpha values exceed the commonly accepted threshold of 0.70, indicating strong internal consistency among the measurement items.

4. Research Results

4.1. Measurement Model Evaluation

Table 2 presents the Chi-square goodness-of-fit statistics for the proposed structural model compared with the saturated and independence models.

The default model yields a Chi-square value of 31.207 with 2 degrees of freedom, which is statistically significant ($p < 0.001$). This result indicates that the hypothesized model does not adequately reproduce the observed covariance matrix. Furthermore, the CMIN/DF ratio is 15.603, which far exceeds the recommended threshold (≤ 3 or ≤ 5), providing strong evidence of poor model fit.

Table 2. CMIN.

Model	NPAR	CMIN	DF	P	CMIN/DF
Default model	19	31.2	2	0.000	15.6
Saturated model	21	0.000	0		
Independence model	6	109.4	15	0.000	7.298

The saturated model, as expected, demonstrates a perfect fit (CMIN = 0) because it exactly reproduces the observed data. In contrast, the independence model shows a very poor fit (CMIN = 109.464, DF = 15, $p < 0.001$; CMIN/DF = 7.298), confirming that the observed variables are not independent.

Although the default model fits the data better than the independence model, its fit remains statistically unacceptable. These findings suggest that the current model specification is inadequate and requires re-specification or structural modification to improve overall goodness of fit.

4.2. Descriptive Analysis

The results indicate a high level of organizational awareness and compliance with Energy Efficiency Rating (EER) requirements, legal obligations, international standards, and product safety, with most respondents agreeing or strongly agreeing across these areas. Strong adherence is evident in the use of accredited laboratories, third-party testing, market surveillance, and harmonized standards, reflecting effective quality control and alignment with global norms. However, responses reveal uncertainty in some areas, particularly MEPS compliance and the use and awareness of the HAZM platform, suggesting knowledge gaps and inconsistent application. Overall, while compliance and safety practices are robust, targeted training and clearer guidance are needed to strengthen MEPS implementation and HAZM utilization.

Table 3 shows that the mean values of all constructs range from 3.61 to 4.32, indicating that respondents generally agree to strongly agree with the statements measuring green supply chain practices and Energy Efficiency Rating (EER). EER records the highest mean (M = 4.32, SD = 0.64), reflecting a strong perceived level of compliance and effectiveness of energy efficiency practices. High mean scores

Table 3. Descriptive statistics and correlation.

Constructs	Mean	Std. Deviation	1	2	3	4	5	6
Eco-design	4.0316	0.94343	1					
Green Distribution	3.6140	0.58016	0.362	1				
Green Purchasing	3.9298	0.92014	0.894**	0.548*	1			
Green Manufacturing	4.0789	1.07061	0.872**	0.186	0.861**	1		
Green Reverse Logistics	4.0000	0.94281	0.762**	0.372	0.865**	0.716**	1	
EER	4.3158	0.63590	0.338	0.014	0.413	0.448	0.327	1

are also observed for Green Manufacturing, Eco-design, Green Reverse Logistics, and Green Purchasing, demonstrating strong organizational commitment to environmentally responsible practices, while Green Distribution reports the lowest mean, suggesting moderate agreement. Overall, standard deviations below 1.1 indicate acceptable dispersion and relatively consistent perceptions among respondents.

The correlation analysis further reveals strong and statistically significant positive relationships among the green supply chain dimensions, highlighting a high level of integration in green practices. Eco-design is strongly correlated with Green Purchasing, Green Manufacturing, and Green Reverse Logistics, while Green Purchasing also shows strong associations with Green Manufacturing and Green Reverse Logistics. These results suggest that organizations adopting one green practice are likely to implement others, reflecting a coherent and synergistic approach to green supply chain management.

With respect to EER, the strongest positive relationship is observed with Green Manufacturing, followed by Green Purchasing and Eco-design, indicating that production-oriented and upstream environmental practices play a more influential role in enhancing energy efficiency performance. Green Reverse Logistics shows a modest association with EER, whereas Green Distribution demonstrates a negligible and non-significant relationship, suggesting a limited direct impact in this context. Overall, the findings indicate strong adoption and integration of green practices, meaningful associations with EER, and no immediate multicollinearity concerns, supporting the suitability of the data for further multivariate analysis such as regression or SEM.

4.3. Hypotheses Testing

In this study, AMOS software was used to test the hypotheses that included the impact of the green supply chain dimensions on EER of the Manufacturing industry in Oman. Figure 2 illustrates the structural model used to test the research hypotheses.

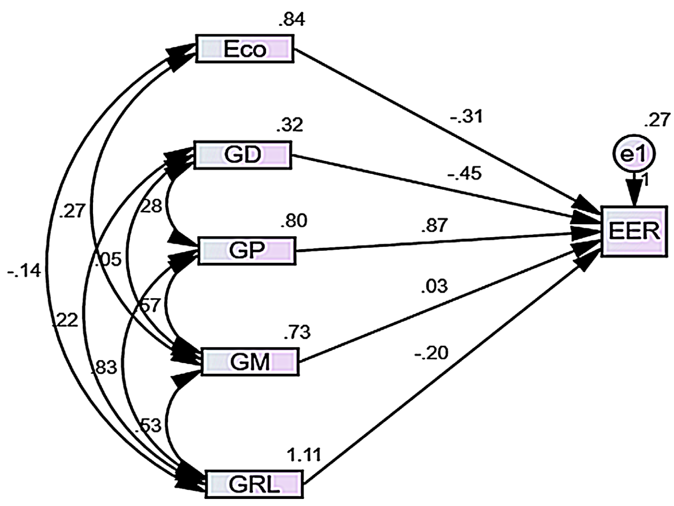

Figure 2. SEM for the impact of green supply chain on EER.

The structural model illustrates the relationships between green supply chain practices (Eco-design, Green Distribution, Green Purchasing, Green Manufacturing, and Green Reverse Logistics) and Energy Efficiency Rating (EER). The standardized path coefficients indicate that Green Purchasing ($\beta = 0.87$) has the strongest positive effect on EER, suggesting that environmentally responsible procurement practices contribute most substantially to improving energy efficiency performance. In contrast, Eco-design ($\beta = -0.31$) and Green Distribution ($\beta = -0.45$) exhibit negative effects on EER, while Green Manufacturing ($\beta = 0.03$) shows a very weak positive effect, and Green Reverse Logistics ($\beta = -0.20$) demonstrates a modest negative influence. These results indicate that not all green practices exert a direct positive impact on energy efficiency outcomes.

The model also shows strong correlations among the green supply chain constructs, confirming that these practices are highly interrelated and tend to be implemented collectively rather than independently. This high degree of intercorrelation suggests the presence of shared underlying dimensions of environmental management and may partially explain why several direct paths to EER are weak or non-significant when modeled simultaneously. Such overlap can reduce the unique explanatory power of individual constructs in the structural model.

Finally, the error term associated with EER (e1 = 0.27) indicates that a proportion of variance in energy efficiency performance remains unexplained by the included predictors. Combined with the previously reported poor model fit indices, the figure suggests that the current model may suffer from specification issues, such as multicollinearity among predictors or missing mediating variables. Overall, while green practices are strongly interconnected, their direct effects on EER appear limited, implying that their influence may be indirect or mediated through other organizational or regulatory factors.

5. Discussion

The hypothesis results reveal a clear variation in the impact of green supply chain practices on Energy Efficiency Rating (EER). H1 (Eco-Design → EER) was found to have a negative or weak direct effect and is therefore not supported. Similarly, H2 (Green Distribution → EER) showed a negligible and statistically non-significant effect, leading to its rejection. In contrast, H3 (Green Purchasing → EER) demonstrated the strongest positive impact among all variables and is supported. H4 (Green Manufacturing → EER) indicated a minimal effect and is not supported. Finally, H5 (Green Reverse Logistics → EER) showed a modest association; however, its direct effect was weak, and thus it is also not supported.

The findings showed that high adoption of green practices: All green supply chain constructs and Energy Efficiency Rating (EER) recorded high mean values, indicating that organizations generally demonstrate strong commitment to environmentally responsible practices and energy efficiency compliance.

Strong integration among green supply chain dimensions: Eco-design, Green Purchasing, Green Manufacturing, and Green Reverse Logistics are highly and positively correlated, suggesting that green practices are implemented in an integrated and mutually reinforcing manner rather than in isolation. Green Purchasing as the strongest predictor: Among all constructs, Green Purchasing shows the strongest positive effect on EER, indicating that environmentally responsible procurement plays a key role in enhancing energy efficiency performance.

Limited or negative direct effects of other practices: Eco-design, Green Distribution, and Green Reverse Logistics exhibit negative or weak direct effects on EER, while Green Manufacturing shows a negligible impact, suggesting that these practices may not directly translate into improved energy efficiency outcomes. Model limitations and unexplained variance: Despite strong correlations among green practices, the overall model fit is weak and a portion of EER variance remains unexplained, indicating potential multicollinearity and the need to consider mediating variables or alternative model specifications in future research.

6. Recommendations, Limitations, and Future Research

The study found that green supply chains (eco-design, green distribution, green procurement, green manufacturing, and green reverse logistics) have an impact on energy efficiency rating (EER). This study specifically recommends that the Government of the Sultanate of Oman integrate the EER program into public procurement evaluation criteria, ensuring that energy efficiency and compliance metrics are systematically considered in tender assessments to promote green practices and incentivize environmentally responsible business behavior. The program should also be formally embedded as a key instrument in the 11th Five-Year Development Plan (2026-2030), incorporating requirements into regulatory frameworks, investment planning, and operational practices to enhance the competitiveness of the Omani products, align with international quality and energy efficiency standards, and strengthen access to global markets. In parallel, the program should support the transition toward a green and circular economy aligned with national priorities and global sustainability trends, promote energy security through diversified and renewable energy sources, and encourage rationalized energy consumption to reduce the ecological footprint of industrial activities and reinforce national energy independence. Moreover, the Program should mandate as a normative reverence to OMAN BULDING CODE. Finally, the government should prioritize and empower the EER program, expand its regulatory scope to cover a broader range of products, strengthen related regulations, and promote sustainable practices across industries, thereby supporting Oman's national energy goals and contributing to the successful achievement of Oman Vision 2040, the Paris Agreement, and the SDGs.

While Oman's EER program has great potential to improve energy efficiency, promote sustainable practices and support national development goals, it also faces some limitations. The program is relatively new, placing the country at a relatively backward stage in terms of energy efficiency, compared to other countries with more mature energy efficiency initiatives. Consequently, there is limited availability of data and empirical evidence due to the program's recent implementation and historically low focus on this area, which may affect the comprehensiveness of analysis and the ability to draw long-term conclusions about its effectiveness. As well, awareness of the EER program among economic operators remains low, which may hinder effective implementation, reduce compliance rates, and limit the program's impact on promoting energy efficiency and sustainable practices across industries. Future researchers may study the effectiveness and impact of the EER program across different sectors, including compliance levels, energy savings, environmental outcomes, and ways to enhance awareness and implementation among stakeholders.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

References

[1] Blind, K., Mangelsdorf, A. and Pohlisch, J. (2018) The Effects of Cooperation in Accreditation on International Trade: Empirical Evidence on ISO 9000 Certifications. *International Journal of Production Economics*, **198**, 50-59. https://doi.org/10.1016/j.ijpe.2018.01.033

[2] Corbett, C.J. and Yeung, A.C.L. (2008) Special Issue on Meta-Standards in Operations Management: Cross-Disciplinary Perspectives. *International Journal of Production Economics*, **113**, 1-2. https://doi.org/10.1016/j.ijpe.2007.02.044

[3] Blind, K. and Heß, P. (2023) Stakeholder Perceptions of the Role of Standards for Addressing the Sustainable Development Goals. *Sustainable Production and Consumption*, **37**, 180-190. https://doi.org/10.1016/j.spc.2023.02.016

[4] Al-Nawafah, S.S., Al-Shorman, H.M., Aityassine, F.L.Y., Khrisat, F.A., Hunitie, M.F.A., Mohammad, A., *et al.* (2022) The Effect of Supply Chain Management through Social Media on Competitiveness of the Private Hospitals in Jordan. *Uncertain Supply Chain Management*, **10**, 737-746. https://doi.org/10.5267/j.uscm.2022.5.001

[5] Castka, P., Prajogo, D., Sohal, A. and Yeung, A.C.L. (2015) Understanding Firms Selection of Their ISO 9000 Third-Party Certifiers. *International Journal of Production Economics*, **162**, 125-133. https://doi.org/10.1016/j.ijpe.2015.01.012

[6] Si-dai, G., Cheng-Peng, L., Hang, L. and Ning, Z. (2021) Influence Mechanism of Energy Efficiency Label on Consumers' Purchasing Behavior of Energy-Saving Household Appliances. *Frontiers in Psychology*, **12**, Article ID: 711854. https://doi.org/10.3389/fpsyg.2021.711854

[7] ISO/IEC 17000:2020 (2020) Conformity Assessment—Vocabulary and General Principles. International Organization for Standardization.

[8] Kavosa, M. and Lapiņa, I. (2016) Certification of Persons: An Important Conformity Assessment Procedure. *ICEM*-2016: 21*st International Scientific Conference* "*Smart and Efficient Economy*: *Preparation for the Future Innovative Economy*", Brno, 19-20 May 2016, 294.

[9] National Institute of Standards and Technology (NIST) (2010) ABC's of Conformity Assessment. https://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.2000-01.pdf?utm_source=chatgpt.com

[10] Khanzada, F. (2024) Conformity Assessment: Relevance of Quality in the Age of In-

dustry 4.0. In: Bhatnagar, A., *et al*., Eds., *Handbook of Quality System, Accreditation and Conformity Assessment*, Springer, 1-28.
https://doi.org/10.1007/978-981-99-4637-2_1-1

[11] Kumar, V. and Albashrawi, S. (2022) Quality Infrastructure of Saudi Arabia and Its Importance for Vision 2030. *MAPAN*, **37**, 97-106.
https://doi.org/10.1007/s12647-021-00523-4

[12] Ministry of Commerce, Industry and Investment Promotion (MoCIIP) (2021) Ministerial Decision No. 190/2021 Issuing the Technical Regulation on the Conformity.
https://mjla.gov.om/decisions/ar/1088/show/1492

[13] Ninlawan, C., Seksan, P., Tossapol, K. and Pilada, W. (2010) The Implementation of Green Supply Chain Management Practices in Electronics Industry. *Proceedings of the International Multi-Conference of Engineers and Computer Scientists*, Vol. 3, 1563-1568.
https://www.iaeng.org/publication/IMECS2010/IMECS2010_pp1563-1568.pdf?utm_source=chatgpt.com

[14] Chin, T.A., Tat, H.H. and Sulaiman, Z. (2015) Green Supply Chain Management, Environmental Collaboration and Sustainability Performance. *Procedia CIRP*, **26**, 695-699. https://doi.org/10.1016/j.procir.2014.07.035

[15] Hsu, C.W. and Hu, A.H. (2008) Green Supply Chain Management in the Electronic Industry. *International Journal of Environmental Science & Technology*, **5**, 205-216.
https://doi.org/10.1007/bf03326014

[16] Grant, D.B. and Shaw, S. (2019) Environmental or Sustainable Supply Chain Performance Measurement Standards and Certifications. In: Sarkis, J., Ed., *Handbook on the Sustainable Supply Chain*, Edward Elgar Publishing, 357-376.
https://doi.org/10.4337/9781786434272.00024

[17] Oelze, N., Gruchmann, T. and Brandenburg, M. (2020) Motivating Factors for Implementing Apparel Certification Schemes—A Sustainable Supply Chain Management Perspective. *Sustainability*, **12**, Article No. 4823.
https://doi.org/10.3390/su12124823

[18] Safarzadeh, S., Hafezalkotob, A. and Jafari, H. (2022) Energy Supply Chain Empowerment through Tradable Green and White Certificates: A Pathway to Sustainable Energy Generation. *Applied Energy*, **323**, Article ID: 119601.
https://doi.org/10.1016/j.apenergy.2022.119601

[19] Sarkis, J., Zhu, Q. and Lai, K. (2011) An Organizational Theoretic Review of Green Supply Chain Management Literature. *International Journal of Production Economics*, **130**, 1-15. https://doi.org/10.1016/j.ijpe.2010.11.010

[20] Rao, P. and Holt, D. (2005) Do Green Supply Chains Lead to Competitiveness and Economic Performance? *International Journal of Operations & Production Management*, **25**, 898-916. https://doi.org/10.1108/01443570510613956

[21] Jabbour, A.B.L.d.S., Frascareli, F.C.d.O. and Jabbour, C.J.C. (2015) Green Supply Chain Management and Firms' Performance: Understanding Potential Relationships and the Role of Green Sourcing and Some Other Green Practices. *Resources, Conservation and Recycling*, **104**, 366-374.
https://doi.org/10.1016/j.resconrec.2015.07.017

[22] Seuring, S. and Müller, M. (2008) From a Literature Review to a Conceptual Framework for Sustainable Supply Chain Management. *Journal of Cleaner Production*, **16**, 1699-1710. https://doi.org/10.1016/j.jclepro.2008.04.020

[23] Chien, M.K. and Shih, L.H. (2007) An Empirical Study of the Implementation of Green Supply Chain Management Practices in the Electronics Industry and Their Re-

lation to Organizational Performances. *International Journal of Environmental Science & Technology*, **4**, 383-394.

[24] Testa, F. and Iraldo, F. (2010) Shadows and Lights of GSCM (Green Supply Chain Management): Determinants and Effects of These Practices Based on a Multi-National Study. *Journal of Environmental Management*, **91**, 1680-1692.

[25] Vachon, S. and Klassen, R.D. (2006) Extending Green Practices across the Supply Chain: The Impact of Upstream and Downstream Integration. *International Journal of Operations & Production Management*, **26**, 795-821. https://doi.org/10.1108/01443570610672248

[26] Laosirihongthong, T., Adebanjo, D. and Choon Tan, K. (2013) Green Supply Chain Management Practices and Performance. *Industrial Management & Data Systems*, **113**, 1088-1109. https://doi.org/10.1108/imds-04-2013-0164

[27] Khan, S.A.R., Qianli, D. and Zhang, Y. (2018) Supply Chain and Transport Sustainability Practices in China: A Green Agenda. *Sustainability*, **10**, Article No. 294.

[28] Mutingi, M., Mapfaira, H. and Monageng, R. (2014) Green Supply Chain Management in SMEs: A Case of Plastic Manufacturing Companies in Botswana. *Journal of Industrial Engineering and Management*, **7**, 689-710.

[29] Khan, S.A.R. and Qianli, D. (2017) Impact of Green Supply Chain Management Practices on Firms' Performance: An Empirical Study from the Perspective of Pakistan. *Environmental Science and Pollution Research*, **24**, 16829-16844. https://doi.org/10.1007/s11356-017-9172-5

[30] Bhutto, M.Y., Liu, X., Soomro, Y.A., Ertz, M. and Baeshen, Y. (2020) Adoption of Energy-Efficient Home Appliances: Extending the Theory of Planned Behavior. *Sustainability*, **13**, Article No. 250. https://doi.org/10.3390/su13010250

[31] Mathias, J.A., Juenger, K.M. and Horton, J.J. (2023) Advances in the Energy Efficiency of Residential Appliances in the US: A Review. *Energy Efficiency*, **16**, 1-21. https://doi.org/10.1007/s12053-023-10114-8

[32] Wang, Y., Wang, J. and He, W. (2022) Development of Efficient, Flexible and Affordable Heat Pumps for Supporting Heat and Power Decarbonisation in the UK and Beyond: Review and Perspectives. *Renewable and Sustainable Energy Reviews*, **154**, Article ID: 111747. https://doi.org/10.1016/j.rser.2021.111747

[33] Mahlia, T.M.I. and Saidur, R. (2010) A Review on Test Procedure, Energy Efficiency Standards and Energy Labels for Room Air Conditioners and Refrigerator-Freezers. *Renewable and Sustainable Energy Reviews*, **14**, 1888-1900. https://doi.org/10.1016/j.rser.2010.03.037

[34] Mlecnik, E., Visscher, H. and van Hal, A. (2010) Barriers and Opportunities for Labels for Highly Energy-Efficient Houses. *Energy Policy*, **38**, 4592-4603. https://doi.org/10.1016/j.enpol.2010.04.015

[35] Evans, M., Roshchanka, V. and Graham, P. (2017) An International Survey of Building Energy Codes and Their Implementation. *Journal of Cleaner Production*, **158**, 382-389. https://doi.org/10.1016/j.jclepro.2017.01.007

[36] Herrando, M., Cambra, D., Navarro, M., de la Cruz, L., Millán, G. and Zabalza, I. (2016) Energy Performance Certification of Faculty Buildings in Spain: The Gap between Estimated and Real Energy Consumption. *Energy Conversion and Management*, **125**, 141-153. https://doi.org/10.1016/j.enconman.2016.04.037

[37] Paul, A., Baumhögger, E., Elsner, A., Reineke, M., Hueppe, C., Stamminger, R., *et al.* (2022) Impact of Aging on the Energy Efficiency of Household Refrigerating Appliances. *Applied Thermal Engineering*, **205**, Article ID: 117992.

https://doi.org/10.1016/j.applthermaleng.2021.117992

[38] Johansson, M.T. and Thollander, P. (2018) A Review of Barriers to and Driving Forces for Improved Energy Efficiency in Swedish Industry—Recommendations for Successful In-House Energy Management. *Renewable and Sustainable Energy Reviews*, **82**, 618-628. https://doi.org/10.1016/j.rser.2017.09.052

[39] Zhang, A., Diabat, A. and Kharabsheh, R. (2017) Supply Chain Management for Improved Energy Efficiency: Review and Opportunities. *Journal of Cleaner Production*, **162**, S120-S130.

[40] Qin, Q., Jiang, M., Xie, J. and He, Y. (2021) Game Analysis of Environmental Cost Allocation in Green Supply Chain under Fairness Preference. *Energy Reports*, **7**, 6014-6022. https://doi.org/10.1016/j.egyr.2021.09.020

[41] Zhu, Q., Sarkis, J. and Lai, K. (2007) Green Supply Chain Management: Pressures, Practices and Performance within the Chinese Automobile Industry. *Journal of Cleaner Production*, **15**, 1041-1052. https://doi.org/10.1016/j.jclepro.2006.05.021

[42] Beheshtinia, M.A. and Fathi, M. (2022) Energy-Efficient and Sustainable Supply Chain in the Manufacturing Industry. *Energy Science & Engineering*, **11**, 357-382. https://doi.org/10.1002/ese3.1337

[43] Gong, Y., Liu, Z., Wu, S., Pu, S., Zhang, X. and Chen, L. (2023) Study on the Technological Inductive Effects of Product Information Label: Evidence from the Energy-Efficiency Labeling System in China. *Sage Open*, **13**. https://doi.org/10.1177/21582440231194141