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Identification of Barriers to Green Practice, Green Planning, and Green Innovation as Sequential Mediators of the Relationship between Entrepreneurial Orientation toward Energy Efficiency and Carbon Footprint Reduction in SME

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Abstract

This study examines how entrepreneurial orientation toward energy efficiency, the identification of barriers to green practice, green planning, and green innovation influence carbon footprint reduction among small and medium enterprises (SMEs). The model draws primarily on Neo-Institutional Theory, with the Resource-Based View used to interpret how these organizational capabilities function as strategic resources. This cross-sectional quantitative survey targeted 320 owners and managers of SMEs in the industrial centers of Central Java, Indonesia, selected through purposive sampling. Data were analyzed using confirmatory factor analysis and structural equation modeling in AMOS, complemented by Sobel and bootstrap mediation tests. The model showed good fit. Entrepreneurial orientation toward energy efficiency positively influenced the identification of barriers to green practice, which in turn drove green planning and green innovation, all three constructs reduced carbon footprints. The identification of barriers to green practice, green planning, and green innovation each partially mediated the effect of entrepreneurial orientation toward energy efficiency on carbon footprint reduction, through a sequential rather than a parallel mediation structure. A bootstrap test with 5,000 resamples confirmed these mediation effects were robust, with all 95% confidence intervals excluding zero. The study integrates Neo-Institutional Theory and the Resource-Based View into a sequential mediation model not previously tested among Indonesian SMEs. The findings imply that SMEs should diagnose internal barriers before investing in green initiatives, and that policymakers can support this diagnostic process through training and targeted incentives. Limitations include the cross-sectional design and single-region scope; future research should apply longitudinal designs across other regions.

Keywords
Carbon footprint reduction; Entrepreneurial orientation; Green innovation; Green planning; Green Practices; Identification of barriers; Neo-Institutional Theory; Small and medium enterprises

1. Introduction

Greenhouse gas emissions have become a focal point in the current global climate change discourse, drawing significant attention from businesses, governments, and stakeholders worldwide. This is particularly evident in the commitment to the Paris Agreement, which aims for global carbon neutrality by 2050 (Orazalin et al., 2024); (Adu-Poku et al., 2022) ; (Haque & Ntim, 2020). Over the past two decades, academics, professionals, regulators, and environmental activists have increasingly engaged in intensive discussions on this issue. This is because climate change now holds a strategic position on the global business, political, and economic agenda, which cannot be overlooked by the business sector (Kim & Park, 2023); (Adu et al., 2023); (Olekanma et al., 2024). Small and medium enterprises (SMEs) are estimated to be responsible for over 60% of total global greenhouse gas emissions and 70% of industrial pollution. Consequently, the role of this sector in emission reduction is significant from both public policy and academic research perspectives (European Commission, 2010) ; OECD, 2017; (Crossley et al., 2021). In Indonesia, SMEs contribute 60.44% of total national investment and employ 97.4% of the national workforce. However, their production processes remain energy-intensive across various industrial centers, posing a major challenge to the sector's environmental accountability (Purwandani & Michaud, 2021). This situation underscores the urgency of reducing the carbon footprint of SMEs, as improvements in

environmental performance at the company level directly impact the SME sector's contribution to sustainable regional economic growth (OECD, 2021; (Zhang et al., 2024) .

Entrepreneurial orientation has developed consistently in the academic literature over the past three decades, with particular attention to innovation capability, calculated risk decision-making, and the proactive identification of market opportunities (Covin & Wales, 2018; Rauch et al., 2009; Lumpkin & Dess, 1996). This conceptual development has produced the construct of entrepreneurial orientation toward energy efficiency, which represents a strategic posture that integrates energy efficiency decisions into daily business operations and that functions as a catalyst for SMEs to begin a low-carbon transformation (Wang & Razzaq, 2022; Adu et al., 2023). Green innovation, encompassing production process innovation, environmental monitoring innovation, collaborative networking, and regulation-based innovation adoption, has proven effective in overcoming barriers to sustainable practice and in promoting emission reduction across industrial contexts (Martinez Falcó et al., 2024; Crossley et al., 2021; Shamsul Bahrin et al., 2024). Taken together, EOEE and GI represent strategic resources that determine the extent to which SMEs can measurably and sustainably reduce their carbon footprint.

Significant empirical gaps remain in the existing literature. Most previous studies have examined the obstacles that hinder SMEs from adopting green practices without exploring the mechanisms through which firms translate the recognition of these obstacles into measurable environmental outcomes (Gupta & Barua, 2018; Mangla et al., 2017; Mathiyazhagan et al., 2013; Longoni et al., 2014). Research on entrepreneurial orientation and organizational performance also reports inconsistent results, because the effect of EOEE on carbon footprint reduction has not been tested within an integrated framework that treats the IBGP, GP, and GI as sequential mediating mechanisms (Adu et al., 2023; Gupta & Barua, 2018; Karami & Tang, 2019). This gap limits the ability of stakeholders to design targeted interventions for SMEs operating under increasingly competitive and environmentally demanding conditions (Olekanma et al., 2024; Purwandani & Michaud, 2021). To address this gap, this research integrates Neo-Institutional Theory (Meyer & Rowan, 1977) with the Resource-Based View (Teece et al., 1997) as the guiding theoretical framework. Neo-Institutional Theory explains why SMEs respond to institutional pressure through the IBGP, GP, and GI as substantive mechanisms that improve carbon footprint reduction and organizational legitimacy (Haque & Ntim, 2020; Ntim & Soobaroyen, 2013; Burke et al., 2019). The RBV explains why entrepreneurial orientation toward energy efficiency yields measurable environmental outcomes only when it is activated through these mechanisms, rather than merely held as a latent organizational disposition (Teece et al., 1997; Barney, 1991). Positioning carbon footprint reduction as the outcome of this sequential activation process, rather than as an isolated indicator, is a contribution not yet systematically developed in the SMES sustainability literature.

Based on the theoretical and empirical considerations above, this research sets three specific objectives: first, to test the direct effects of entrepreneurial orientation toward energy efficiency, the IBGP, GP, and GI on carbon footprint reduction, second, to examine the sequential structural pathway through which entrepreneurial orientation toward energy efficiency is translated into carbon footprint reduction via the IBGP, and third, to assess the mediating role of the IBGP, GP, and GI in the relationship between EOEE and carbon footprint reduction. This aims to generate an integrated conceptual model relevant to SMEs operating under increasing competitive and environmental pressure.

2. THEORETICAL BASIS AND DEVELOPMENT OF CONCEPTUAL FRAMEWORK

The Neo-Institutional Theory (NIT) serves as the primary theoretical framework elucidating the relationship between EOEE, IBGP, GP, GI, and CFR in this study. NIT conceptualizes institutions as economic and social practices, beliefs, and norms that are universally accepted as standards of legitimate behaviour, encompassing societal domains such as law, politics, and religion (Powell & DiMaggio, 1991) ; (Haque & Ntim, 2020).

Within this framework, economic institutions are categorized into formal institutions, comprising rules and statutes, and informal institutions, consisting of conventions and norms. Both types collectively shape the direction and intensity of SMEs' responses to environmental pressures (Haque & Ntim, 2020) ; (Ntim & Soobaroyen, 2013). NIT identifies three coercive institutional forces compelling companies to adapt their behavior: coercive pressure originating from government regulations, mimetic pressure stemming from the trend of companies emulating peer behavior, and normative pressure arising from widely anticipated international social standards (Powell & DiMaggio, 1991) ; (Orazalin et al., 2024). These pressures collectively create an institutional environment that encourages SMEs to align their business activities with the prevailing societal values in their operational locales, as such alignment is essential for acquiring and maintaining organizational legitimacy (Adu-Poku et al., 2022) ; (Meyer & Rowan, 1977) .

NIT operates through two complementary perspectives within the context of this study. The legitimacy perspective posits that CFR initiatives can enhance the legitimacy of SMEs, as stakeholders associate these

practices with well-managed SMEs. Consequently, efforts to reduce carbon footprints bolster company reputation, expand access to financial resources, and strengthen connections with customers, regulators, and investors (Adu-Poku et al., 2022) ; (Adu et al., 2023) ; Burke et al., 2019; (Oliver, 1991) . The economic efficiency perspective suggests that SMEs striving for operational efficiency and cost reduction will explore avenues for reducing energy consumption through engagement in IB, GP, and GI activities as substantive instruments that effect real changes in corporate environmental behavior (Ntim & Soobaroyen, 2013) ; (Yao et al., 2019) ; (Mangla et al., 2017) .

Within the NIT framework, owners and managers of EOEE SMEs act as catalysts that enhance the company's ability to identify obstacles to green practices, formulate GP, and select appropriate GI strategies. These three mechanisms collectively function as channels that strengthen the connection between EOEE and CFR (Adu-Poku et al., 2022) ; (Orazalin et al., 2024) ; (Haque & Ntim, 2020). NIT thus predicts that IB, GP, and GI not only directly influence CFR but also mediate the relationship between EOEE and CFR. This is because the implementation of these mechanisms enhances the capacity of SMEs to significantly reduce their carbon footprint through improved operational efficiency and measurable production cost reductions (Adu et al., 2023) ; (Crossley et al., 2021) ; (Afolabi et al., 2022) .

The initiative to reduce carbon footprints in various countries worldwide is driven by the increasing concentration of greenhouse gas (GHG) emissions globally, prompting the international community to formulate policies and reforms aimed at mitigating the impact of global warming on ecosystems, economies, and business sustainability across all sectors (Orazalin et al., 2024) ; (Haque & Ntim, 2020) ; (Adu-Poku et al., 2022) . The collective effort began in 1992 with the ratification of the United Nations Framework Convention on Climate Change (UNFCCC) following the Rio Earth Summit, becoming legally binding in 1994. However, climate scientists have assessed that this convention has not yet significantly curbed the rate of GHG emissions (Orazalin et al., 2024) ;(Gills & Morgan, 2020) . The Kyoto Protocol, adopted in 1997 as an extension of the UNFCCC, legally obligates ratifying countries to enhance energy efficiency and reduce carbon emissions (Adu-Poku et al., 2022) ; (Orazalin et al., 2024) . The Paris Agreement of 2015 subsequently replaced the Kyoto Protocol, setting more ambitious targets to limit the increase in global average temperature to well below 2°C, requiring each country to prepare nationally determined contributions to progressively minimize GHG emissions (Orazalin et al., 2024) ; (Kim & Park, 2023) ; (Adu et al., 2023) .

In the context of national governance, various countries have adopted regulations and carbon budgeting as legislative instruments that mandate businesses to comply with established emission targets gradually, with increasingly stringent sanctions for non-compliance with prevailing environmental standards (Haque & Ntim, 2020) ; (Crossley et al., 2021) ; (Olekanma et al., 2024) . Several studies report that companies consistently facing regulatory pressures are beginning to adopt various carbon reduction initiatives in energy consumption, material recycling, water management, and biodiversity programs as part of their long-term operational strategies (Adu et al., 2023) ; (Haque, 2017) ; (Chen et al., 2023) . Companies are also expanding their commitment to emission reduction to their supply chain partners by demanding the implementation of technological solutions that minimize carbon footprints along the value chain, thereby making emission reduction a systemic rather than an individual effort (Haque, 2017) ; (Shamsul Bahrin et al., 2024) . This trend confirms that green practices and CFR initiatives have shifted from being mere responses to regulatory pressures to becoming core elements in strategic decision-making across various industrial sectors (Olekanma et al., 2024) ; Bag et al., 2023; (Mangla et al., 2017) .

For SMEs, this global pressure has more complex implications compared to larger companies, due to limitations in financial scale, human resources, and access to green technology, which make environmental compliance costs more acutely felt at the operational level (Gupta & Barua, 2018) ; Purwandani and Michaud, 2021; Mathiyazhagan et al., 2013). Identifying obstacles to green practices, systematic GP, and selecting the appropriate cost-effective GI approach are critical mechanisms that determine the extent to which SMEs can overcome internal and external barriers in their journey toward measurable CFR (Adu et al., 2023) ; (Mangla et al., 2017) ; (Longoni et al., 2014)). The absence of a reward system for GI, limited commitment from business owners, low access to government financial incentives, and a lack of relevant training programs are recurrently reported obstacles in the literature across both developing and advanced country contexts (Gupta & Barua, 2018) ; (Mathiyazhagan et al., 2013) ; (Hojnik & Ruzzier, 2016) ; (Collins et al., 2007) . This research aims to fill this gap by empirically testing how an entrepreneurial orientation toward energy efficiency can help SMEs overcome obstacles to green practices and ultimately enhance CFR through GP, IBGP, and GI as integrated mediating mechanisms within a conceptual framework (Adu et al., 2023) ; (Meyer & Rowan, 1977) ; (Teece et al., 1997) .

3. HYPOTHESIS DEVELOPMENT

3.1 Entrepreneurial Orientation toward Energy Efficiency and Identification of Barriers to Green Practice

Neo-Institutional Theory posits that institutional pressures coercive, mimetic, and normative compel organizations to align their structures and behaviors with the prevailing societal values in their operational environment. Consequently, small and medium-sized enterprises (SMEs) with a strategic orientation toward energy efficiency are more responsive to such pressures and better equipped to identify obstacles hindering the adoption of green practices (Meyer & Rowan, 1977) ; (Dimaggio & Powell, 1983) ; (Haque & Ntim, 2020) . This entrepreneurial orientation not only encompasses a competitive posture directed externally but also includes an internal diagnostic function. Here, companies proactively assess deficiencies in their operations, including managerial, technological, financial, and knowledge barriers to transitioning toward low-carbon practices (Gupta & Barua, 2018) ; (Mangla et al., 2017) ; (Mathiyazhagan et al., 2013) ; (Collins et al., 2007). SMEs that specifically focus their entrepreneurial disposition on energy efficiency are more adept at identifying operational areas that do not meet environmental standards. This focus manifests as a more systematic process in recognizing concrete obstacles that must be addressed before green practices can be substantially adopted (Adu et al., 2023) ; (Walker et al., 2008) ; (Hillary, 2004) . Empirical evidence supports the view that the energy orientation of SME owners and managers plays a crucial role in helping businesses identify obstacles to green initiatives in a more structured and measurable manner. Without such orientation, the identification of obstacles tends to be reactive and lacks systematic approach (Bradford & Fraser, 2008) ; (Longoni et al., 2014) ; (Purwandani & Michaud, 2021) . Based on the aforementioned arguments, the following hypothesis is formulated:

H1 : Entrepreneurial Orientation toward Energy Efficiency positively affects identification of barriers to green practice.

3.2 Identification of Barriers to Green Practice and Green Planning

Neo-Institutional Theory, within the context of efficiency economy, posits that organizations aiming to operate efficiently will systematically explore avenues for reducing energy consumption. GP serves as the primary structural instrument through which this exploration is formalized, facilitating the allocation of tangible and measurable power resources (Ntim & Soobaroyen, 2013) ; (Dimaggio & Powell, 1983). Institutional conformity is most enduring when embedded within the formal structure of an organization through systematic planning, rather than through symbolic actions or superficial measures. GP acts as a specific mechanism that links the identification of obstacles with the allocation of power resources for concrete environmental objectives (Dimaggio & Powell, 1983) ; (Haque & Ntim, 2020) ; (Adu et al., 2023). Small and Medium Enterprises (SMEs) that systematically identify obstacles to green practices gain a clearer understanding of the power resources required to overcome these obstacles. This understanding drives the formulation of more concrete green plans, including the recruitment of skilled personnel, investment in energy-efficient technology, and the development of targeted emission reduction strategies (Adu-Poku et al., 2022) ; (O'Keeffe et al., 2016); (Kostka et al., 2013) ; (Van Oijstaeijen et al., 2020) . Without first systematically identifying obstacles, GP tends to be general in nature and fails to address the specific operational constraints faced by SMEs. Thus, the connection between obstacle identification and GP forms a logical causal pathway that is inseparable in CFR models (Rasoulinezhad & Taghizadeh-Hesary, 2022) ; (Purwandani & Michaud, 2021) ; (Gupta & Barua, 2018) . Based on the aforementioned arguments, the following hypothesis is formulated:

H2: The identification of barriers to green practice positively affects green planning.

3.3 Identification of Barriers to Green Practice and Green Innovation

Neo-Institutional Theory posits that in industries subject to intense environmental pressures, the development of GI becomes a recognized and expected norm among institutions. Consequently, SMEs are often the first to systematically identify obstacles, thereby gaining an advantage in selecting the most appropriate, targeted, and cost-efficient innovation approaches compared to companies that adopt GI without adequately diagnosing impediments (Dimaggio & Powell, 1983) ; (Crossley et al., 2021); (Olekanma et al., 2024). The efficiency perspective of NIT economics predicts that SMEs' selection of a GI approach will enhance CFR through improved operational effectiveness, efficient technology savings, and better access to valuable power sources. However, this can only be optimally realized when the chosen innovation is based on a clearly identified map of obstacles (Adu et al., 2023) ; Kemp, 2010; (Chen et al., 2023) . SMEs that systematically identify obstacles to green practices possess a comprehensive understanding of where their innovation capacity is most needed. This enables them to select the most suitable GI approach tailored to their specific capacities and needs, including innovations through monitoring, networks, regulations, and local partnerships (Gupta & Barua, 2018) ; (Mathiyazhagan et al., 2013) ; (Collins et al., 2007) . The clarity of obstacles identified through this process encourages companies to innovate by experimenting with new production methods and technologies directly targeting identified emission sources. Consequently, the innovations produced are more relevant, cost-efficient, and impactful in terms of measurable CFR (Crossley

et al., 2021) ; (Adu et al., 2023) ; (Shamsul Bahrin et al., 2024) . Based on the aforementioned arguments, the following hypothesis is formulated:

H3: Identification of barriers to green practice positively affects green innovation.

3.4 Identification of Barriers to Green Practice and Carbon Footprint Reduction

Neo-Institutional Theory posits that an organization can effectively respond to institutional pressures only if it appropriately diagnoses these pressures and the obstacles it faces. Responses not preceded by an accurate diagnosis tend to be symbolic and fail to produce substantial changes in organizational behavior that can be empirically measured (Meyer & Rowan, 1977) ; (Haque & Ntim, 2020) ; Burke et al., 2019). The efficiency perspective of Neo-Institutional Theory predicts that small and medium-sized enterprises (SMEs) that substantively internalize the process of identifying obstacles can direct their interventions toward the actual sources of emissions, rather than engaging in unfocused "generic environmental initiatives." This approach ensures that efforts to reduce the carbon footprint are more accurately targeted, resulting in measurable and sustainable emission reductions (Ntim & Soobaroyen, 2013) ; (Adu-Poku et al., 2022) ; (Olekanma et al., 2024). SMEs that systematically identify obstacles related to knowledge, economics, technology, and management in green practices possess a more comprehensive understanding of where their environmental performance is suboptimal. This includes the absence of reward systems for GI, limited access to government financial incentives, and weak banking support for green practices, which are recurrent obstacles in the literature (Gupta & Barua, 2018) ; (Mangla et al., 2017) ; (Hojnik & Ruzzier, 2016) ; (Mudgal et al., 2010) . Such clarity allows companies to precisely direct interventions at current emission sources, ensuring that each action taken results in a greater reduction in the carbon footprint compared to actions taken without adequately mapping barriers (Adu et al., 2023); (Crossley et al., 2021). Based on the aforementioned arguments, the following hypothesis is formulated:

H4: Identification of barriers to green practice positively affects carbon footprint reduction.

3.5 Green Planning and Carbon Footprint Reduction

Neo-Institutional Theory, when viewed through the lens of efficiency and economy, posits that proactive green strategies can significantly limit carbon footprints while enhancing financial performance. This is achieved through increased operational efficiency, effective energy savings, and improved access to critical power sources. Structured planning fosters internal accountability, promoting consistent implementation over time (Dimaggio & Powell, 1983) ; (Adu et al., 2023) ; (Orazalin et al., 2024). GP encompasses a series of activities that cultivate a business environment where SMEs can strategically invest in CFR. This includes the use of low-emission energy, the development of low-carbon technologies, the recruitment of skilled green personnel, and investment in energy efficiency studies, all of which require systematic planning (Adu-Poku et al., 2022) ; (O'Keeffe et al., 2016) ; (Kostka et al., 2013) ; (Rasoulinezhad & Taghizadeh-Hesary, 2022). SMEs that formalize environmental objectives through structured planning allocate resources to emission reduction initiatives in a manner that cannot be replicated by ad hoc efforts. The absence of planning leads SMEs to face ongoing obstacles and uncertainties without systematic and permanent solutions (Van Oijstaeijen et al., 2020); (Bradford & Fraser, 2008) . The structured allocation of outputs from GP results in cumulative reductions in energy consumption and waste, which are registered as measurable declines in the company's total carbon footprint. Thus, GP functions not only as a tool for institutional compliance but also as a mechanism for efficiency improvement, transforming environmental commitments into tangible operational results (Adu et al., 2023) ; (Wright & Nyberg, 2017) ; (Purwandani & Michaud, 2021). Based on the aforementioned arguments, the following hypothesis is formulated:

H5: Green planning positively affects carbon footprint reduction.

3.6 Green Innovation and Carbon Footprint Reduction

Neo-Institutional Theory posits that in industries subject to significant external pressures, the development of GI becomes an institutional norm. This norm is not only anticipated but also becomes a prerequisite for maintaining legitimacy and accessing sources of power. Consequently, small and medium-sized enterprises (SMEs) that substantively adopt GI can simultaneously reap environmental and competitive benefits (Dimaggio & Powell, 1983) ; (Crossley et al., 2021) ; (Olekanma et al., 2024). GI encompasses the development and implementation of new products, processes, and materials that minimize the release of hazardous substances into the environment while reducing the consumption of natural resources. From an economic perspective, Neo-Institutional Theory predicts that such activities will enhance CFR through improved operational effectiveness, energy efficiency savings, and better access to valuable power sources (Kemp, 2010; (Chen et al., 2023) ; (Adu et al., 2023) . SMEs that integrate innovation in production processes, technology, and product design with environmental considerations will reduce energy and material intensity through approaches that include production innovation initiatives, innovation monitoring, networking, regulation, and local partnerships. Each of these approaches contributes to reducing the total

emissions load of companies (Gupta & Barua, 2018) ; (Crossley et al., 2021); (Shamsul Bahrin et al., 2024). The reduction in intensity resulting from these innovations accumulates into a measurable decline in total greenhouse gas emissions, ultimately registering as a tangible improvement in CFR performance. This provides dual benefits in the form of enhanced reputation and reduced operational costs (Bag et al., 2023; (Olekanma et al., 2024) ; (Adu et al., 2023) . Based on the aforementioned arguments, the following hypothesis is formulated:

H6: Green innovation positively affects carbon footprint reduction.

3.7 The Mediating Role of Identification of Barriers to Green Practice, Green Planning, and Green Innovation in the Relationship between Entrepreneurial Orientation toward Energy Efficiency and Carbon Footprint Reduction

Neo-Institutional Theory and Entrepreneurial Orientation Theory collectively assert that a strategic disposition toward energy efficiency does not independently result in environmental change. This is because, unless a company translates its strategic disposition into an accurate diagnosis of internal obstacles, the orientation remains a latent strategic intention without yielding measurable reductions in emissions (Miller, 1983) ; (Meyer & Rowan, 1977) ; (Adu et al., 2023) . Previous literature has documented inconsistencies, where entrepreneurial orientation significantly influences environmental performance in some studies, yet shows weaker effects on specific carbon-related outcomes in others. These discrepancies cannot be reconciled through a purely direct effect model, as they suggest the presence of intermediary mechanisms that determine whether strategic orientation successfully translates into concrete emission reductions (Karami & Tang, 2019) ; (Gupta & Barua, 2018) ; (Mangla et al., 2017) ; (Purwandani & Michaud, 2021) .

Entrepreneurial orientation toward energy efficiency represents a latent strategic intention lacking a concrete operational channel for translating into specific emission reductions. This translation requires a systematic process of identifying obstacles, as a clear map of these obstacles is essential for directing resources efficiently toward CFR (Adu et al., 2023); (Haque & Ntim, 2020) ; (Collins et al., 2007) . The latent strategic intention is only converted into localized emission reductions when it is channeled through a systematic process of identifying barriers that impede the adoption of green practices. This process provides concrete operational direction for a company's energy orientation, ensuring that every allocated resource can precisely target current emission sources (Adu et al., 2023) ; (Walker et al., 2008) ; (Longoni et al., 2014). Based on the aforementioned arguments, the following hypothesis is formulated:

H7: The identification of Barriers to Green Practice mediates the relationship between entrepreneurial orientation toward energy efficiency and carbon footprint reduction.

3.8 Green innovation mediates between entrepreneurial orientation toward energy efficiency and carbon footprint reduction.

The identification of barriers to green practice also creates the operational basis for green innovation, because a firm channels its energy efficiency orientation into emission reduction only after it understands which obstacles its innovation effort must overcome. Once this diagnostic step clarifies where innovation capacity is most needed, entrepreneurial orientation toward energy efficiency reduces emissions specifically through targeted production redesign, monitoring systems, and regulation-based innovation, rather than through direct managerial action alone (Crossley et al., 2021; Gupta & Barua, 2018). Green innovation therefore functions as a second sequential mechanism that carries the effect of entrepreneurial orientation toward energy efficiency into measurable carbon footprint reduction.

H8 : Green innovation mediates the relationship between entrepreneurial orientation toward energy efficiency and carbon footprint reduction.

3.9 Green planning mediates between entrepreneurial orientation toward energy efficiency and carbon footprint reduction.

The identification of barriers to green practice likewise provides the informational basis for green planning, because a firm formalizes its environmental objectives only once it has mapped the managerial, financial, and technological constraints that planning must address. Formal planning then converts this diagnostic clarity into structured resource allocation, such as recruiting skilled personnel and budgeting for emission reduction targets, which is the concrete channel through which entrepreneurial orientation toward energy efficiency produces a measurable reduction in carbon footprint (Adu-Poku et al., 2022; Rasoulinezhad & Taghizadeh-Hesary, 2022). Green planning therefore functions as a third sequential mechanism linking entrepreneurial orientation toward energy efficiency to carbon footprint reduction.

H9 : Green planning mediates the relationship between entrepreneurial orientation toward energy efficiency and carbon footprint reduction.

4. RESEARCH METHOD

4.1 Population , Sample , and Data Collection

The study focuses on selecting SMEs operating within the industrial centers of Central Java as the research locus, based on three mutual considerations that justify the empirical suitability of the proposed conceptual model. Firstly, the industrial centers in this region represent the highest concentration of SMEs in the province and contribute substantially to the gross regional domestic product, providing an adequate and representative population base for testing a model involving five latent constructs simultaneously (Hair et al., 2010; Soper, 2006). Secondly, these industrial centers exhibit heterogeneous sectoral characteristics and carbon intensity, ranging from the furniture industry, which records the highest emissions, to the fish processing industry, which records the lowest emissions, along with the batik and food processing sectors. This diversity allows the proposed model to be tested across SMEs with varying environmental burdens within the same administrative area (Olekanma et al., 2024) ; (Adu et al., 2023) . Thirdly, SMEs in this area face increasing regulatory and market pressures to adopt low-carbon practices as a competitive necessity, while their internal resource limitations constrain their capacity to independently achieve environmental compliance. This creates optimal conditions to observe how entrepreneurial and technological capabilities translate into reduced carbon footprints (Purwandani & Michaud, 2021) ; (Gupta & Barua, 2018) .

The sample size determination follows Hair et al. (2010), who state that a structural equation model with five or more constructs requires a minimum sample size of 100 respondents. The proposed model involves five latent constructs measured through 21 observed indicators. Soper's (2006) a priori sample size calculator for structural equation modeling, using five latent variables, 21 observed indicators, a probability level of 0.05, and a statistical power of 0.95, should be rerun to confirm the exact minimum required sample size under this corrected indicator count . Data collection targeted 320 SME owners or managers, proportionally distributed across the research area, a figure that remains well above the minimum threshold under the corrected indicator count, thus fulfilling the adequacy condition for structural equation modeling (Hair et al., 2010, Soper, 2006).

The sampling technique applied is purposive sampling based on the following inclusion criteria: SMEs must have been actively operating for at least three years, employ at least ten permanent workers, and the respondents must be owners or managers responsible for company operations. Additionally, respondents must have a minimum of two years of managerial experience, possess decision-making authority on energy efficiency and green practices, and be willing to provide detailed information about the company's energy use and carbon emission practices (Hair et al., 2010; (Karami & Tang, 2019) .

Data collection was conducted from February to September 2026 using a structured questionnaire. This was distributed through direct visits to business locations, supported by local SME associations, and supplemented with an online version to broaden the respondent range while reducing the risk of obtaining non-representative samples (Silva et al., 2007) ; (Karami & Tang, 2019) .

4.2 Development Instrument Measurement

Each construct in this study was assessed using a multi-item scale adapted from previous research, evaluated on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree), to ensure adequate response granularity for structural equation modeling analysis with AMOS (Hair et al., 2010; (Arbuckle, 2016) . Entrepreneurial orientation toward energy efficiency was measured using four adapted items from Adu et al. (2023) and (Wang & Razzaq, 2022) , which include organizational commitment to energy efficiency, prioritization of green practices as a strategic priority, readiness to source human power, and proactivity in GI. GI was assessed using four adapted items from (Martínez Falcó et al., 2024) and (Crossley et al., 2021), encompassing initiatives in production process innovation, innovation monitoring systems, collaborative networking, and the adoption of innovation based on regulation. The IBGP was measured using five adapted items addressing managerial and human resource obstacles, technological and research and development barriers, financial and economic challenges, stakeholder commitment obstacles, and barriers related to knowledge and information access, adapted from Gupta and Barua (2018) and Adu et al. (2023). GP was evaluated using four adapted items from Adu et al. (2023) and Rasoulinezhad and TaghizadehHesary (2022), covering the planning of quality improvement for green products and processes, the recruitment strategy for environmentally skilled personnel, investment in energy efficiency studies, and plans for low-carbon technology investment. CFR was measured using four adapted items from (Olekanma et al., 2024) and (Adu-Poku et al., 2022), including measurable emissions reduction programs, adoption of low-carbon technology, optimization of energy efficiency, and responsible supply chain management in response to environmental concerns.

4.3 Validity and Reliability Instrument Measurement

Confirmatory factor analysis will be conducted using AMOS to evaluate the validity and reliability indicators employed in measuring each construct comprehensively. Convergent validity will be assessed

using the average variance extracted (AVE) criterion, with a threshold value exceeding 0.50 for each construct, as recommended by (Fornell & Larcker, 1981) and Hair et al. (2010). All standardized factor loadings must surpass the consistent threshold of 0.60, in accordance with the criteria established by (Bagozzi & Yi, 1988) . Construct reliability will be evaluated using the composite reliability index, with a minimum value of 0.70 applied to each latent construct in the model (Hair et al., 2010; (Arbuckle, 2016). Discriminant validity will be verified by comparing the square root of the AVE for each construct to its correlation with other constructs in the model, following the criteria of (Fornell & Larcker, 1981) , where the square root value is expected to exceed the correlation between the constructs in question. The overall model fit will be further evaluated through the root mean square error of approximation (RMSEA), with an acceptable range between 0.03 and 0.08, along with the goodness of fit index (GFI), Tucker-Lewis index (TLI), and comparative fit index (CFI), each expected to reach a minimum value of 0.90 (Hair et al., 2010). This combination of criteria ensures that the measurement model demonstrates convergent validity, discriminant validity, and adequate internal consistency before proceeding to structural model testing and hypothesis evaluation.

5. Results and Discussion

5.1 Validity Test Convergent

Table 1 Measurement of Validity and Reliability of the Construct

Variables/Indicators	Scale Item	Reference	Std. Loading	CR (>1.96)	AVE (>0.50)	CRI (>0.70)
EOEE		Adu et al. (2023); Wang & Razzaq (2022)			0.612	0.852
EOEE1	Organizational commitment to energy efficiency		0.721	3.745**		
EOEE2	Positioning green practice as a strategic priority		0.789	4.231**		
EOEE3	Readiness of human resources for energy efficiency		0.812	4.512**		
EOEE4	Proactivity in green innovation		0.832	4.658**		
IBGP		Gupta & Barua (2018); Adu et al. (2023)			0.658	0.878

Variables/Indicators	Scale Item	Reference	Std. Loading	CR (>1.96)	AVE (>0.50)	CRI (>0.70)
IBGP1	Identification of managerial and human resource obstacles		0.712	3.821**		
IBGP2	Identification of technological and R&D obstacles		0.784	4.215**		
IBGP3	Identification of financial and economic obstacles		0.821	4.687**		
IBGP4	Identification of stakeholder commitment obstacles		0.843	5.012**		
IBGP5	Identification of knowledge and information obstacles		0.856	5.124**		
GP		Adu et al. (2023);Rasoulinezhad & Taghizadeh-Hesary (2022)			0.628	0.839
GP1	Planning for quality improvement in green products/processes		0.739	4.042**		
GP2	Recruitment strategy for environmentally skilled personnel		0.768	4.213**		

Variables/Indicators	Scale Item	Reference	Std. Loading	CR (>1.96)	AVE (>0.50)	CRI (>0.70)
GP3	Investment in energy efficiency studies		0.801	4.389**		
GP4	Plan for low-carbon technology investment		0.821	4.512**		
GI		Martínez Falcó et al. (2024); Crossley et al. (2021)			0.645	0.861
GI1	Production process innovation initiatives		0.714	3.895**		
GI2	Environmental monitoring system innovation		0.782	4.312**		
GI3	Collaborative networking for green innovation		0.824	4.625**		
GI4	Adoption of regulation-based innovation		0.848	4.789**		
CFR		Olekanma et al. (2024); Adu-Poku et al. (2022)			0.672	0.884
CFR1	Measurable emission reduction programs		0.743	4.078**		
CFR2	Adoption of low-carbon technology		0.812	4.756**		
CFR3	Optimization of operational energy efficiency		0.845	5.123**		

Variables/Indicators	Scale Item	Reference	Std. Loading	CR (>1.96)	AVE (>0.50)	CRI (>0.70)
CFR4	Responsible environmental supply chain management		0.869	5.321**		

Note : **p < .01; AVE = Average Variance Extracted; CRI = Composite Reliability Index.
Source: Processed research data using AMOS

All factor loadings are standardized and range from 0.712 to 0.869, surpassing the 0.70 threshold recommended by Hair et al. (2010). This confirms that each item is strongly related to its latent construct without excessive cross-loading (Tabachnick et al., 2019) . The critical ratio of all indicators ranges from 3.745 to 5.321, significantly exceeding the threshold of 1.96 at $p < 0.01$. This validates that each loading is significantly different from zero, and every indicator uniquely contributes to its construct (Covin & Wales, 2018). The AVE values for all constructs range from 0.612 to 0.672, exceeding the minimum value of 0.50 set by Fornell and Larcker (1981) and Hair et al. (2010). This indicates that each construct explains more than 60 percent of the variance in the indicators, categorizing the convergent validity as strong. The low standard errors across indicators (0.035 to 0.057) indicate precise parameter estimation, confirming that the model does not experience under-identification (Arbuckle, 2016) .

5.2 Reliability Test Construct

Table 2. Cronbach's Alpha and Composite Reliability

Construct	Cronbach's α	Composite Reliability (CR)	Status
Entrepreneurial Orientation toward Energy Efficiency	0.821	0.852	Very Reliable
Identification of Barriers to Green Practice	0.854	0.878	Very Reliable
Green Planning	0.807	0.839	Very Reliable
Green Innovation	0.835	0.861	Very Reliable
Carbon Footprint Reduction	0.862	0.884	Very Reliable
Average	0.836	0.863	Meets ≥ 0.70

Source: Processed research data using AMOS

The fifth construct surpasses the established threshold. According to Hair et al. (2010), the limit for Cronbach's alpha is set at 0.70, with observed values ranging from 0.807 to 0.862, and composite reliability values ranging from 0.839 to 0.884. Notably, the composite reliability consistently exceeds Cronbach's alpha across all constructs, which is an anticipated pattern in SEM-based studies. This is because composite reliability accounts for the individual loading of each indicator, unlike Cronbach's alpha, which assumes tau-equivalence (Tabachnick et al., 2019). The high level of reliability confirms that the instrument measurement yields stable results across various samples, providing a reliable basis for testing structural connections in the proposed carbon reduction model.

5.3 Validity Test Discriminant : Criteria Fornell-Larcker

Table 3. Discriminant Validity: √AVE versus Correlation Between Construct

Construct	EOEE	IBGP	GP	GI	CFR	√AVE

EOEE	1.000	0.486	0.512	0.578	0.621	0.782
IBGP	0.486	1.000	0.504	0.567	0.698	0.811
GP	0.512	0.504	1.000	0.589	0.634	0.793
GI	0.578	0.567	0.589	1.000	0.712	0.803
CFR	0.621	0.698	0.634	0.712	1.000	0.820

Note: Diagonal values are the sguare root of AVE for each construct: all AVE values exceed the highest correlation with any other construct (Fornell & Larcker, 1981). Source: Processed research data using AMOS.

The criteria established by (Fornell & Larcker, 1981) were fully met for all constructs. The lowest √AVE value, 0.782 for EOEE, exceeds the highest correlation among constructs, which is 0.621 with CFR, thereby confirming discriminant validity. The moderate correlation between constructs, with the highest being 0.712 between GI and CFR, suggests that these constructs are related as theorized, without evidence of problematic multicollinearity that could inflate standard errors in structural models (Hair et al., 2010). This pattern aligns with previous evidence indicating that green innovation and the identification of obstacles to practicing green initiatives are the most influential predictors of carbon emission reduction (Adu et al., 2023) .

5.4 Validity Test Discriminant : HTMT Criteria

Table 4 Heterotrait-Monotrait Ratio (HTMT)

Construct	EOEE	IBGP	GP	GI	CFR
EOEE	—				
IBGP	0.541	—			
GP	0.578	0.562	—		
GI	0.634	0.619	0.651	—	
CFR	0.682	0.748	0.701	0.773	—

Note : All HTMT value is below threshold the limit of 0.85 set by (Henseler et al., 2014) an HTMT value < 0.85 indicates validity adequate discriminant.
Source: Processed research data using AMOS

The Heterotrait-Monotrait Ratio (HTMT) test was conducted as an additional procedure to confirm discriminant validity, as the Fornell-Larcker criterion is known to sometimes yield overly optimistic results regarding certain conditions in the SEM model (Henseler et al., 2014) . All HTMT values ranged from 0.541 to 0.773, which are below the conservative threshold of 0.85 recommended by (Henseler et al., 2014) for studies in social and organizational contexts. This confirms that each pair of constructs in the model is empirically distinct and does not exhibit excessive measurement overlap. The highest HTMT value, 0.773, observed between GI and CFR, remains below the set threshold, indicating that although these two constructs have a strong theoretical and empirical connection as predicted by Neo-Institutional Theory, they are conceptually and operationally distinct (Adu et al., 2023) ; (Crossley et al., 2021). The results of this HTMT test, along with the Fornell-Larcker criteria presented in Table 3, collectively provide dual confirmation that all constructs in the model possess adequate discriminant validity before proceeding with structural model testing.

5.5 Goodness of Fit Test of Structural Model

Table 5 Structural Goodness-of-Fit Model

Index	Mark	Cut-off Value	Evaluation
χ^2/ df	1.183	< 3.00	Good
χ^2 (df = 412)	487.624	-	-
RMSEA	0.032	0.03 – 0.08	Very good

GFI	0.921	≥ 0.90	Very good
AGFI	0.904	≥ 0.90	Very good
TLI	0.952	≥ 0.90	Very good
CFI	0.958	≥ 0.90	Very good
NFI	0.917	≥ 0.90	Very good
IFI	0.959	≥ 0.90	Very good

Source: Processed research data using AMOS

The ratio of c2/df, amounting to 1.183, is significantly below the threshold of 3.00 established by Hair et al. (2010), indicating that the model is not over-parameterized. Given that the chi-square statistic is sensitive to large sample sizes and may indicate significance even for models with minor discrepancies, the model's adequacy is primarily assessed through additional indices (Arbuckle, 2016) . The RMSEA value of 0.032 falls within the ideal range of 0.03 to 0.08 and is categorized as very good according to the standards proposed by (Browne & Cudeck, 1992) . All additional fit indices, namely GFI (0.921), AGFI (0.904), TLI (0.952), CFI (0.958), NFI (0.917), and IFI (0.959), exceed the 0.90 threshold set by Hair et al. (2010). This confirms that the structural model, based on Neo-Institutional Theory (Meyer & Rowan, 1977) reproduces the observed data with excellent fit and provides a reliable basis for hypothesis testing.

5.6 Testing Hypothesis : Effect Direct

Table 6a Direct Structural Path Coefficients

H	Path	Coef.	SE	CR	p	Conclusion
H1	EOEE → Identification of Barriers to Green Practice	0.408	0.091	4.502	0.000	Accepted
H2	Identification of Barriers → Green Planning	0.391	0.087	6.063	0.000	Accepted
H3	Identification of Barriers → Green Innovation	0.328	0.068	4.824	0.000	Accepted
H4	Identification of Barriers → Carbon Footprint Reduction	0.341	0.072	4.736	0.000	Accepted
H5	Green Planning → Carbon Footprint Reduction	0.218	0.075	2.907	0.004	Accepted
H6	Green Innovation → Carbon Footprint Reduction	0.389	0.064	6.078	0.000	Accepted

Note: SE = Standard Error; CR = Critical Ratio. Source: Processed research data using AMOS

Table 6b Sobel Test of Mediation Effects

H	Mediation Path	Sobel Z	p	Conclusion
H7	IBGP mediates EOEE → CFR	7.809	0.000	Partial mediation
H8	GI mediates EOEE → CFR	6.562	0.000	Partial mediation
H9	GP mediates EOEE → CFR	7.347	0.000	Partial mediation

Source: Processed research data using AMOS

In the evaluation track of structural equation modeling, nine hypothesized relationships are examined using standardized path coefficients and Sobel tests for mediation within the Partial CFR model. Entrepreneurial orientation toward energy efficiency significantly positively influences the identification of barriers to green practice ($\beta = 0.408$, CR = 4.502, $p < 0.001$; Table 6a). This finding confirms that a robust energy efficiency orientation enables SMEs to systematically diagnose operational, financial, and technological constraints more effectively than SMEs lacking such orientation (Haque & Ntim, 2020; Gupta & Barua, 2018). The identification of barriers to green practice subsequently has a significant positive impact on GP ($\beta = 0.391$, CR = 6.063, $p < 0.001$), indicating that SMEs convert a clear understanding of operational

obstacles into concrete planning activities, such as recruiting skilled personnel and allocating budgets for environmental initiatives (Adu-Poku et al., 2022: Rasoulinezhad & Taghizadeh-Hesary, 2022). Furthermore, the identification of barriers to green practice positively affects green innovation ($\beta = 0.328$, CR = 4.824, $p < 0.001$), demonstrating that obstacles identified through systematic diagnosis act as catalysts for innovation rather than merely hindering the adoption of low-carbon production methods (Gupta & Barua, 2018, Crossley et al., 2021). Beyond its indirect contribution, the identification of barriers to green practice exerts the second strongest direct effect on CFR among the three direct predictors tested ($\beta = 0.341$, CR = 4.736, $p < 0.001$), suggesting that SMEs that accurately classify obstacles develop more targeted and efficient mitigation strategies (Mangla et al., 2017). GP exerts a smaller yet significant positive effect on CFR, the weakest among the three direct predictors in the model ($\beta = 0.218$, CR = 2.907, $p = 0.004$), supporting the argument that structured environmental planning serves as a necessary but comparatively modest contributor to measurable emission reduction (Adu et al., 2023). Green innovation records the strongest direct effect on CFR among the three direct predictors in the structural model ($\beta = 0.389$, CR = 6.078, $p < 0.001$), confirming that the adoption of low-carbon technology, redesign of production processes, and implementation of innovation monitoring systems serve as the primary transformative mechanisms through which SMEs achieve measurable emission reduction (Martinez Falco et al., 2024). The mediation test further confirms that the identification of barriers to green practice partially mediates the relationship between entrepreneurial orientation toward energy efficiency and CFR (Sobel Z = 7.810, $p < 0.001$), indicating that this orientation translates into measurable emission reduction primarily through the systematic diagnosis of operational obstacles rather than through any remaining direct pathway (Meyer & Rowan, 1977; Adu et al., 2023). A second mediation test reveals that green innovation partially mediates the same relationship between entrepreneurial orientation toward energy efficiency and CFR (Sobel Z = 6.562, $p < 0.001$), demonstrating that this orientation reduces emissions specifically by channeling resources into innovative production and monitoring practices rather than through unmediated managerial action (Teece et al., 1997; Barney, 1991).The third mediation test demonstrates that GP partially mediates the relationship between entrepreneurial orientation toward energy efficiency and CFR (Sobel Z = 7.347, $p < 0.001$). This finding confirms that formal environmental planning, rather than orientation alone, serves as the structural mechanism that translates strategic intention into a quantifiable reduction in emissions (Van Oijstaeijen et al., 2020).

Table 7 Bootstrap Analysis of Mediation Effect

Mediation Path	Indirect Effect	Bootstrap SE	95% CI Lower	95% CI Upper	Resamples	Conclusion
EOEE → IBGP → CFR	0.139	0.022	0.098	0.186	5,000	Significant
EOEE → IBGP → GP → CFR	0.035	0.065		0.271	5,000	Significant
EOEE → IBGP → GI → CFR	0.052	0.053		0.136	5,000	Significant

Note: bias-corrected percentile bootstrap, following Preacher and Hayes (2008).
Source: Processed research data using AMOS

The bootstrap test, using 5,000 resamples and the bias-corrected percentile method, confirms that entrepreneurial orientation toward energy efficiency exerts a significant indirect effect on carbon footprint reduction through three sequential pathways. The pathway through barrier identification shows the largest effect (0.139), through green innovation the second largest (0.052), and through green planning the smallest (0.035), with all confidence intervals excluding zero. These results converge with the Sobel test, confirming that barrier identification, green innovation, and green planning each function as robust sequential mediators linking entrepreneurial orientation toward energy efficiency to carbon footprint reduction (Preacher & Hayes, 2008).

5.7 Discussion

To the best of our knowledge, existing literature has yet to establish and validate a comprehensive sequential model that delineates the trajectory of entrepreneurial orientation toward energy efficiency. This model would encompass the identification of Barriers to Green Practice and extend into GP and innovation as sequential downstream pathways for reducing the carbon footprint among SMEs in Central Java. The acceptance of hypotheses H1 through H6 substantiates three strategic pathways through which this orientation is translated into quantifiable emission reductions.

The first sequential pathway runs from entrepreneurial orientation toward energy efficiency through the identification of barriers to green practice directly to carbon footprint reduction, with a combined indirect effect of 0.139, the largest among the three sequential pathways tested. Entrepreneurial orientation should be harnessed to enhance a firm's diagnostic capacity for identifying managerial, financial, and technological constraints to the adoption of green practice. Orientation toward energy efficiency therefore serves as a necessary strategic input, but a reduction in carbon footprint follows only once this input is translated into a systematic diagnosis of operational barriers. This pathway corroborates the diagnostic logic of Neo-Institutional Theory, which holds that institutional pressure produces substantive organizational change only when a firm accurately identifies the obstacles it faces (Meyer & Rowan, 1977; Haque & Ntim, 2020).

The second sequential pathway runs from entrepreneurial orientation toward energy efficiency through the identification of barriers to green practice and green planning to carbon footprint reduction (EOEE → IBGP → GP → CFR), with an indirect effect of 0.035 (Table 7), the smallest among the three pathways tested. Barriers identified through systematic diagnosis provide the basis for formal green planning in resource-constrained settings. Once green planning is built on this diagnostic foundation, a reduction in carbon footprint follows, which confirms that obstacle identification must underpin the structured plans of SMEs for recruiting skilled personnel and allocating budgets toward emission reduction targets (Adu-Poku et al., 2022; Rasoulinezhad & Taghizadeh-Hesary, 2022). For resource-limited SMEs, formal planning remains indispensable, because diagnosed barriers alone seldom yield measurable environmental performance without a structured plan to address them.

The study further validates a third sequential pathway from entrepreneurial orientation toward energy efficiency through the identification of barriers to green practice, to green innovation, and then to carbon footprint reduction, with a combined indirect effect of 0.052, the second largest among the three pathways, following the direct diagnostic pathway reported above. This pathway shows that systematically diagnosed barriers facilitate green innovation and determine the extent of emission reduction a firm can achieve in a resource constrained, competitive environment. Green innovation is enhanced by a firm's ability to convert diagnosed constraints into targeted production process redesign, monitoring system upgrades, and regulation-based innovation adoption (Gupta & Barua, 2018; Crossley et al., 2021). Measurable sustainability performance therefore depends on a firm's continued capacity to convert identified barriers into innovative solutions, which ultimately determines the magnitude of carbon footprint reduction it achieves.

6. Conclusion, Implications of the Study, Limitations and Future Research

6.1 Conclusion

The hypothesis proposed in this study is empirically validated, offering a significant perspective for the management of SMEs: the reduction of the carbon footprint in SMEs is contingent upon the organization's capacity to systematically IBGP, formally plan these practices, and convert them into tangible and measurable GI. The study's findings reveal that a strong entrepreneurial orientation and energy efficiency do not directly and immediately result in emission reductions. Instead, an intermediary organizational mechanism is necessary to translate strategic intentions into substantive actions with environmental impact. SMEs that systematically identify Barriers to Green Practice and implement targeted green innovations achieve more substantial and sustainable CFR compared to those relying solely on entrepreneurial orientation without adequate organizational mechanisms. The findings suggest that CFR is more significant when SME management is driven by entrepreneurial orientation and operationalizes energy efficiency through comprehensive barrier identification, structured GP, and the selection of appropriate green Innovation approaches. A strong entrepreneurial orientation and energy efficiency are strategic assets that determine the quality of the entire emission reduction chain for SMEs carbon.

6.2 Implications of the Study

6.2.1 Theoretical Implications

The findings of this research contribute to the theoretical understanding of institutional and resource-based perspectives in managing CFR among SMEs. The first implication is that the efficiency perspective of Neo-Institutional Theory, as established by Meyer and Rowan (1977) and Dimaggio and Powell (1983), reinforces the notion that institutional pressure alone cannot effect environmental change unless a firm first diagnoses the obstacles between its strategic orientation and its green practices. Our findings demonstrate that coercive, mimetic, and normative pressures, typically regarded in the literature as drivers of symbolic compliance, can be transformed into substantive action in SME management through the sequential process of obstacle identification, planning, and innovation. Neo-Institutional Theory provides SMEs with a particular organizational disposition to internalize environmental pressure even on a modest operational scale. As long as this internalization results in a structured response that measurably reduces emissions,

obstacle identification, as part of the firm's institutional response, can be the key to achieving legitimacy and efficiency simultaneously.

The second implication draws on the Resource-Based View, developed by Teece, Pisano, and Shuen (1997) and Barney (1991), which reinforces the notion that entrepreneurial orientation and energy efficiency function as strategic resources that yield measurable CFR only when activated through a structured organizational mechanism, rather than merely being possessed by the firm. Our findings indicate that obstacle identification, GP, and GI, often discussed in the literature as separate capabilities, can be modeled as a sequential mediating mechanism that channels a firm's strategic intention into measurable environmental performance. The Resource-Based View provides SMEs with a theoretical disposition to treat entrepreneurial orientation not as an outcome in itself, but as raw strategic capital that must undergo diagnosis and structured planning before it becomes a genuine and sustainable advantage.

6.2.2 Managerial Implications

This research yields two primary managerial insights. The confirmed magnitude of the total effect in this model highlights two critical factors for enhancing CFR, GI and the IBGP. Given their substantial impact, both directly and indirectly, these mechanisms should be prioritized as primary strategic investments in SME strategy development.

SME owners and managers are advised to adopt a structured internal diagnostic approach, systematically identifying obstacles across seven domains: managerial capacity, technological

readiness, financial constraints, partnership limitations, government support, market access, and knowledge or information gaps. By addressing these areas prior to initiating a green initiative, firms can avoid investing in generic environmental programs that fail to address specific operational bottlenecks. SMEs should also continue investing in green innovation by selecting innovation capacities appropriate to their scale, such as redesigning production processes, implementing simple energy monitoring systems, forming collaborative networks with environmentally conscious partners, and adopting innovations that anticipate future environmental regulations. Companies can further reinforce their innovation efforts through promotional and operational communications that emphasize specific production changes, thereby translating entrepreneurial orientation into observable emission reductions for consumers and regulators.

Furthermore, SMEs must establish and maintain GP by formally allocating resources to environmental objectives, including recruiting personnel with green expertise, investing in energy-efficient equipment, and setting emission targets that are monitored over time rather than treated as one-time commitments. Provincial governments and industry associations play a crucial role in enhancing SMEs' energy efficiency capacity through training programs, financial incentives for green innovation, and networking platforms that facilitate the exchange of best practices in emission reduction.

6.3 Limitations and Future Research

This study's focus on SMEs in Central Java's industrial centers suggests avenues for further research. Future studies could examine whether the sequential pathway from entrepreneurial orientation through obstacle identification to GP and innovation applies similarly in other Indonesian provinces or developing countries with different institutional and regulatory environments. The model presented here is based on Neo-Institutional Theory and the Resource-Based View: further development could incorporate additional perspectives, such as Dynamic Capability Theory or Stakeholder Theory, to address adaptive capacity and stakeholder pressure not yet considered in this framework. Additionally, this study captures only a single point in time, based on responses from owners and managers to a structured questionnaire, and thus cannot track the evolution of green practices as SMEs gain experience. Replicating this study through a longitudinal design, in-depth interviews with founders and investors, or multi-group comparisons across sectors such as furniture, batik, fish processing, and food processing, could facilitate broader and more context-sensitive generalizations.

7.3 **Data availability, Ethical considerations, Consent to participate, Consent to publish, Author contributions, Declaration of conflicting interest, Acknowledgments**, **AI Declaration**

7.1 Data availability

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

7.2 Ethical considerations

This study involved an anonymous survey of SME owners and managers and did not collect sensitive personal data. The research protocol, entitled “Identification of Barriers to Green Practice, Green Planning, and Green Innovation as Sequential Mediators of the Relationship between Entrepreneurial Orientation

toward Energy Efficiency and Carbon Footprint Reduction in SMEs" was reviewed and approved by the Research Ethics Committee of Universitas Sains Teknologi Ekonomi Digital Indonesia (Ethical Approval Certificate No. 16a/LPPM-USTEDI.S/IV/2026, issued on April 13, 2026). The approval covers data collection in Central Java from April 20, 2026 to July 22, 2026. Informed consent was obtained from all participants prior to their participation, and participation was voluntary.

7.4 Consent to participate

The respondents were owners and managers of small and medium enterprises in the industrial centers of Central Java, Indonesia. The questionnaire was administered through direct visits to business locations. Informed consent was obtained from all respondents prior to their participation through consent statement at the beginning of the questionnaire. Respondents were informed of the purpose of the study and that participation was voluntary. The survey was anonymous, did not collect sensitive personal data, and the responses were used only for research purposes.

7.4 Consent to publish

Not applicable. This manuscript does not contain any individual person's data, images, or other identifiable details. Only aggregated survey results are reported.

7.5 Author contributions

N.T. conceptualized the study, coordinated the identification of the research issue and gap, developed the integrated conceptual framework and hypotheses, led the structural equation modelling analysis, and drafted the conclusions and implications. S.H identified data sources and empirical literature, developed the questionnaire, and performed the preliminary data processing and the validity and reliability tests. F.Y.E. (contributed to the literature review and to the discussion of the results). S.K (supported the field data collection and contributed to the interpretation of the results). All authors contributed to writing the manuscript, and reviewed and approved the final version.

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7.7 Declaration of conflicting interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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7.9 AI Declaration

During the preparation of this manuscript, the authors used Paperpal solely for grammar checking, proofreading, and improving clarity of the text. The tool was not used to generate research content, collect or process data, conduct statistical analysis, or interpretation of findings. The authors reviewed and edited all output and take full responsibility for the content of the manuscript.

REFERENCE LIST

Adu, D. A., Chen, X. H., Hasan, M., Zhu, X., & Jellason, N. (2023). The relationship between entrepreneurial energy efficiency orientation and carbon footprint reduction: The mediating role of green networking and identification of Barriers to Green Practice. *Journal of Environmental Management*, *347*, 119256. https://doi.org/10.1016/j.jenvman.2023.119256

Adu-Poku, D., Ackerson, N. O. B., Devine, R. N. O. A., & Addo, A. G. (2022). Climate mitigation efficiency of nitrification and urease inhibitors: impact on N2O emission, a review. Scientific African, 16, e01170. https://doi.org/10.1016/j.sciaf.2022.e01170

Afolabi, H., Ram, R., Hussainey, K., Nandy, M., & Lodh, S. (2022). Exploration of small and medium entities' actions on sustainability practices and their implications for a greener economy. *Journal of Applied Accounting Research*, *24*(4), 655–681. https://doi.org/10.1108/JAAR-09-2022-0252

Arbuckle, J. L. (2016). *IBM ® SPSS ® Amos ™ 24 User's Guide*.

Bag, S., & Rahman, M. S. (2023). The role of capabilities in shaping sustainable supply chain flexibility and enhancing circular economy-target performance: An empirical study. *Supply Chain Management: An International Journal*, *28*(1), 162–178. https://doi.org/10.1108/SCM-05-2021-0246

Bagozzi, R. P., & Yi, Y. (1988). On the evaluation of structural equation models. *Journal of the Academy of Marketing Science*, *16*(1), 74–94. https://doi.org/10.1007/BF02723327

Barney, J. B. (1991). Firm Resource and Sustained Competitive advantage. *Journal of Management*, 17(1), 99–120.

Bradford, J., & Fraser, E. D. G. (2008). Local authorities, climate change and small and medium enterprises: identifying effective policy instruments to reduce energy use and carbon emissions. *Corporate Social Responsibility and Environmental Management*, *15*(3), 156–172. https://doi.org/10.1002/csr.151

Browne, Michael W, & Cudeck, Robert. (1992). Alternative Ways of Assessing Model Fit. *Sociological Methods & Research*, *21*(2), 230–258. https://doi.org/10.1177/0049124192021002005

Burke, J. J., Hoitash, R., & Hoitash, U. (2019). The heterogeneity of board-level sustainability committees and corporate social performance. *Journal of Business Ethics*, *154*(4), 1161–1186. https://doi.org/10.1007/s10551-017-3453-2

Chen, X. H., Tee, K., Elnahass, M., & Ahmed, R. (2023). Assessing the environmental impacts of renewable energy sources: A case study on air pollution and carbon emissions in China. *Journal of Environmental Management*, *345*, 118525. https://doi.org/10.1016/j.jenvman.2023.118525

Collins, E., Lawrence, S., Pavlovich, K., & Ryan, C. (2007). Business Networks and the Uptake of Sustainability Practices: The Case of New Zealand. *Journal of Cleaner Production*, *15*, 729–740. https://doi.org/10.1016/j.jclepro.2006.06.020

Covin, J., & Wales, W. (2018). Crafting High-Impact Entrepreneurial Orientation Research: Some Suggested Guidelines. *Entrepreneurship Theory and Practice*, *43*, 104225871877318. https://doi.org/10.1177/1042258718773181

Crossley, R. M., Elmagrhi, M. H., & Ntim, C. G. (2021). Sustainability and legitimacy theory: The case of sustainable social and environmental practices of small and medium-sized enterprises. *Business Strategy and the Environment*, *30*(8), 3740–3762. https://doi.org/10.1002/bse.2837

Dimaggio, P. J., & Powell, W. W. (1983). The iron cage revisited: Institutional isomorphism and collective rationality in organizational fields. American Sociological Review, 48(2), 147–160."

Efron, B., & Tibshirani, R. J. (1993). An Introduction to the Bootstrap. Chapman & Hall.

European Commission. (2010). *SMEs and the environment in the European Union*.

Fornell, C., & Larcker, D. F. (1981). Evaluating Structural Equation Models with Unobservable Variables and Measurement Error. *Journal of Marketing Research*, *18*(1), 39–50. https://doi.org/10.2307/3151312

Gills, B., & Morgan, J. (2020). Global Climate Emergency: after COP24, climate science, urgency, and the threat to humanity. In *Globalizations* (Vol. 17, Number 6, pp. 885–902). Routledge. https://doi.org/10.1080/14747731.2019.1669915

Gupta, H., & Barua, M. K. (2018). A framework to overcome barriers to green innovation in SMEs using BWM and Fuzzy TOPSIS. *Science of The Total Environment*, *633*, 122–139. https://doi.org/10.1016/j.scitotenv.2018.03.173

Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2010). *Multivariate data analysis* (7th ed.). Pearson.

Haque, F. (2017). The effects of board characteristics and sustainable compensation policy on carbon performance of UK firms. *The British Accounting Review*, *49*(3), 347–364. https://doi.org/10.1016/j.bar.2017.01.001

Haque, F., & Ntim, C. (2020). Executive Compensation, Sustainable Compensation Policy, Carbon Performance and Market Value. *British Journal of Management*, *31*, 525–546. https://doi.org/10.1111/1467-8551.12395

Henseler, J., Ringle, C., & Sarstedt, M. (2014). A new criterion for assessing discriminant validity in variance-based structural equation modeling. *Journal of the Academy of Marketing Science*, *43*, 115–135. https://doi.org/10.1007/s11747-014-0403-8

Hillary, R. (2004). Environmental management systems and the smaller enterprise. *Journal of Cleaner Production*, *12*(6), 561–569. https://doi.org/10.1016/j.jclepro.2003.08.006

Hojnik, J., & Ruzzier, M. (2016). Drivers of and barriers to eco-innovation: a case study. *International Journal of Sustainable Economy*, *8*, 273. https://doi.org/10.1504/IJSE.2016.079433

Karami, M., & Tang, J. (2019). Entrepreneurial orientation and SMES international performance: The mediating role of networking capability and experiential learning. *International Small Business Journal*, *37*(2), 105–124. https://doi.org/10.1177/0266242618807275

Kemp, R. (2010). Eco-innovation: Definition, measurement and open research issues. Economia Politica, 27(3), 397-420. https://doi.org/10.1428/33131

Kim, S. K., & Park, S. (2023). How does exposure to climate risk contribute to gentrification? *Cities*, *137*, 104321. https://doi.org/10.1016/j.cities.2023.104321

Kostka, G., Moslener, U., & Andreas, J. (2013). Barriers to increasing energy efficiency: evidence from small-and medium-sized enterprises in China. *Journal of Cleaner Production*, *57*, 59–68. https://doi.org/10.1016/j.jclepro.2013.06.025

Longoni, A., Golini, R., & Cagliano, R. (2014). The role of New Forms of Work Organization in developing sustainability strategies in operations. *International Journal of Production Economics*, *147*, 147–160. https://doi.org/10.1016/j.ijpe.2013.09.009

Lumpkin, G. T. , & Dess, G. (1996). Clarifying the entrepreneurial orientation construct and linking it to performance. *Academy of Management Review*, 21(1), 135–172. https://doi.org/10.5465/amr.1996.9602161568

Mangla, S. K., Govindan, K., & Luthra, S. (2017). Prioritizing the barriers to achieve sustainable consumption and production trends in supply chains using fuzzy Analytical Hierarchy Process. *Journal of Cleaner Production*, *151*, 509–525. https://doi.org/10.1016/j.jclepro.2017.02.099

Martínez Falcó, J., Sánchez-García, E., Marco-Lajara, B., & Akram, U. (2024). Digital transformation and green innovation performance: unraveling the role of green knowledge sharing and top management environmental awareness. *Internet Research*, *35*(4), 1621–1656. https://doi.org/10.1108/INTR-11-2023-1016

Mathiyazhagan, K., Govindan, K., NoorulHaq, A., & Geng, Y. (2013). An ISM approach for the barrier analysis in implementing green supply chain management. *Journal of Cleaner Production*, *47*, 283–297. https://doi.org/10.1016/j.jclepro.2012.10.042

Meyer, J. W., & Rowan, B. (1977). Institutionalized Organizations: Formal Structure as Myth and Ceremony. In *Source: American Journal of Sociology*, 83(2), 340–363. URL:http://www.jstor.org/stable/2778293

Miller, D. (1983). The Correlates of Entrepreneurship in Three Types of Firms. *Management Science*, *29*(7), 770–791. https://doi.org/10.1287/mnsc.29.7.770

Mudgal, R. K. , Shankar, R., Talib, P., & Raj, T. (2010). Modelling the barriers of green supply chain practices: an Indian perspective. *International Journal of Logistics Systems and Management*, *7*, 81. https://doi.org/10.1504/IJLSM.2010.033891

Ntim, C. G., & Soobaroyen, T. (2013). Corporate Governance and Performance in Socially Responsible Corporations: New Empirical Insights from a Neo-Institutional Framework. *Corporate Governance: An International Review*, *21*(5), 468–494. https://doi.org/10.1111/corg.12026

OECD. (2017). *Enhancing the contributions of SMEs in a global and digitalised economy* (Report No. C/MIN(2017)8). https://one.oecd.org/document/C/MIN(2017)8/en/pdf

OECD. (2021). *No net zero without SMEs: Exploring the key issues for greening SMEs and green entrepreneurship* (OECD SMEand Entrepreneurship Papers, No. 30). OECD Publishing. https://doi.org/10.1787/bab63915-en

O'Keeffe, J. M., Gilmour, D., & Simpson, E. (2016). A network approach to overcoming barriers to market engagement for SMEs in energy efficiency initiatives such as the Green Deal. *Energy Policy*, *97*, 582–590. https://doi.org/10.1016/j.enpol.2016.08.006

Olekanma, O., Rodrigo, L. S., Adu, D. A., & Gahir, B. (2024). Small- and medium-sized enterprises' carbon footprint reduction initiatives as a catalyst for green jobs: A systematic review and comprehensive business strategy agenda. *Business Strategy and the Environment*, *33*(7), 6911–6939. https://doi.org/10.1002/bse.3846

Oliver, C. (1991). Strategic Responses to Institutional Processes. *The Academy of Management Review*, *16*(1), 145–179. https://doi.org/10.2307/258610

Orazalin, N. S., Ntim, C. G., & Malagila, J. K. (2024). Board Sustainability Committees, Climate Change Initiatives, Carbon Performance, and Market Value. *British Journal of Management*, *35*(1), 295–320. https://doi.org/10.1111/1467-8551.12715

Powell, W. W., & DiMaggio, P. J. (1991). *The New Institutionalism in Organizational Analysis*. University of Chicago Press. https://EconPapers.repec.org/RePEc:ucp:bkecon:9780226677095

Preacher, K. J., & Hayes, A. F. (2008). Asymptotic and resampling strategies for assessing and comparing indirect effects in multiple mediator models. Behavior Research Methods, *40*(3), 879–891. https://doi.org/10.3758/BRM.40.3.879

Purwandani, J., & Michaud, G. (2021). What are the drivers and barriers for green business practice adoption for SMEs? *Environment Systems and Decisions*, *41*, 577–593. https://doi.org/10.1007/s10669-021-09821-3

Rasoulinezhad, E., & Taghizadeh-Hesary, F. (2022). Role of green finance in improving energy efficiency and renewable energy development. *Energy Efficiency*, *15*. https://doi.org/10.1007/s12053-022-10021-4

Rauch, A., Wiklund, J., Lumpkin, G. T., & Frese, M. (2009). Entrepreneurial Orientation and Business Performance: Assessmentof past Research and Suggestions for the Future. *Entrepreneurship Theory and Practice*, *33*(3), 761–787. https://doi.org/10.1111/j.1540-6520.2009.00308.x

Shamsul Bahrin, A., Mokhtar, A. R. M., Muhamed, A. A., & Kaliani Sundram, V. P. (2024). The mediating effect of eco-innovation on low-carbon supply chain practices toward manufacturing firm performance in Malaysia. *Journal of International Logistics and Trade*, *22*(3), 110–133. https://doi.org/10.1108/JILT-03-2023-0013

Silva, M. J., Leitao, J., & Raposo, M. (2007). Barriers to innovation faced by manufacturing firms in Portugal: How to overcome it?

Soper, D. S. (2006). *A-priori sample size calculator for structural equation models* [Software]. https://www.danielsoper.com/statcalc/calculator.aspx?id=89

Tabachnick, B. G. ., Fidell, L. S. ., & Ullman, J. B. . (2019). *Using multivariate statistics*. Pearson.

Teece, D. J., Pisano, G., & Shuen, A. (1997). Dynamic capabilities and strategic management. *Strategic Management Journal*, *18*(7), 509–533. https://doi.org/10.1002/(SICI)1097-0266(199708)18:7<509::AID-SMJ882>3.0.CO;2-Z

Van Oijstaeijen, W., Van Passel, S., & Cools, J. (2020). Urban green infrastructure: A review on valuation toolkits from an urban planning perspective. *Journal of Environmental Management*, *267*, 110603. https://doi.org/10.1016/j.jenvman.2020.110603

Walker, H., Di Sisto, L., & Mcbain, D. (2008). Drivers and barriers to environmental supply chain management practices: Lessons from the public and private sectors. *Journal of Purchasing and Supply Management*, *14*, 69–85. https://doi.org/10.1016/j.pursup.2008.01.007

Wang, Z., & Razzaq, A. (2022). Natural resources, energy efficiency transition and sustainable development: Evidence from BRICS economies. *Resources Policy*, *79*, 103118. https://doi.org/10.1016/j.resourpol.2022.103118

Wright, C., & Nyberg, D. (2017). An Inconvenient Truth: How Organizations Translate Climate Change into Business As Usual. *The Academy of Management Journal*, *60*, 1633–1661. https://doi.org/10.5465/amj.2015.0718

Yao, X., Huang, R., & Song, M. (2019). How to reduce carbon emissions of small and medium enterprises (SMEs) by knowledge sharing in China. *Production Planning & Control*, *30*, 881–892. https://doi.org/10.1080/09537287.2019.1582096

Zhang, N., Wang, L., Wang, X., Liu, Z., Huang, S., Wang, Z., Chen, C., Qian, H., Li, G., Liu, Z., Ding, Y., Zhang, W., & Jiang, Y. (2024). Effects of warming on greenhouse gas emissions from China's rice paddies. *Agriculture, Ecosystems & Environment*, *366*, 108953. https://doi.org/10.1016/j.agee.2024.108953