Journal of Reproducible Research (JRR)
Volume (1) - 2025 - e- ISSN - 2948-5282

Renewable Energy Adoption among SMEs: System Literature Review

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Information of Article

Article history:
Received: July 2025
Revised: August 2025
Accepted: Sep 2025
Available Online: Sep 2025

Keywords:
Renewable Energy Adoption, Small and Medium-Sized Enterprises, Sustainability, Energy Transition, Green Technology.

Abstract
The transition to renewable energy is a critical component of global efforts to mitigate climate change, reduce reliance on fossil fuels, and advance sustainable development. Small and medium-sized enterprises, which make up the majority of businesses worldwide, play a central role in this transition due to their combined environmental impact and significant contribution to economic activity. Despite growing awareness of clean energy solutions, the rate of renewable energy adoption among small and medium-sized enterprises remains highly uneven across sectors and regions. This study conducts a systematic literature review of forty-three peer-reviewed articles published between 2014 and 2025 to examine the key factors influencing renewable energy adoption in this sector. The review identifies four primary motivators: long-term cost savings, energy reliability, environmental responsibility, and alignment with regulatory or market expectations. Major obstacles include limited financial capacity, high capital costs, technological complexity, and policy instability. The study also highlights the importance of mediating and moderating factors such as government support, leadership commitment, industry dynamics, and the involvement of external consultants. The findings emphasize the need for integrated policy frameworks and targeted support mechanisms to enable broader and more equitable participation of small and medium-sized enterprises in the global renewable energy transition.

1. Introduction

The transition to renewable energy (RE) has emerged as a pivotal strategy in mitigating the adverse impacts of climate change, reducing carbon emissions, and ensuring long-term environmental and economic sustainability. As global energy demands rise, particularly in rapidly industrializing economies, the role of small and medium-sized enterprises (SMEs) in adopting sustainable energy solutions becomes increasingly vital. SMEs constitute a significant portion of the global business ecosystem and are often considered engines of innovation, employment, and regional development. However, despite their importance, their participation in renewable energy transitions remains under-researched and underutilized (Adanma & Ogunbiyi, 2024; Martins et al., 2022). The adoption of renewable energy within SMEs is not only an environmental imperative but also an economic opportunity. Research shows that when SMEs integrate renewable technologies such as solar, wind, and bioenergy into their operations, they can achieve both operational cost reductions and enhanced resilience to volatile fossil fuel markets (Awamleh et al., 2025; Atchike et al., 2022). In developing countries, where energy access is often unreliable or inconsistent, renewable energy adoption among SMEs can foster productivity gains and socioeconomic development (Asif et al., 2023; Zhindon-Almeida & Ruiz-Carrillo,

2025). For instance, studies from Jordan (Al Naimat & Liang, 2023; Hamed et al., 2023) and Ghana (Ofori et al., 2022) have demonstrated how the strategic deployment of renewable solutions can transform SME competitiveness while reducing ecological footprints.

Nonetheless, the journey toward widespread renewable energy adoption among SMEs is fraught with challenges. Numerous studies have identified key barriers such as high initial investment costs, technological uncertainties, lack of awareness, regulatory ambiguity, and insufficient access to financing mechanisms (Bugwandin et al., 2025; Luthra et al., 2015; Obuseh et al., 2025). These barriers are often exacerbated in low- and middle-income countries, where policy enforcement is weak and market incentives are poorly structured (Kylili et al., 2025; Painuly & Wohlgemuth, 2021). Even in advanced economies, SMEs frequently lag behind larger firms in renewable energy adoption due to resource limitations and limited access to technical expertise (Herce et al., 2024; Horky & Fidrmuc, 2024). Moreover, the decision to adopt renewable energy is not purely economic, it is shaped by a variety of contextual and organizational factors. Studies indicate that organizational culture, leadership commitment, and government policy support play crucial roles in shaping SME energy decisions (Sobar, 2025; Alshahrani et al., 2024; Avwioroko & Ibegbulam, 2024). Policies that offer tax credits, subsidies, or low-interest financing have been shown to positively influence adoption rates, especially when coupled with capacity-building programs and awareness campaigns (Girardeau et al., 2021; Oosthuizen & Inglesi-Lotz, 2022). Additionally, the presence of external consultants and energy service providers can significantly ease the adoption process by offering technical guidance and implementation strategies tailored to SME constraints (Avwioroko & Ibegbulam, 2024; Meijer et al., 2019).

The complexity of RE adoption decisions among SMEs also necessitates a deeper understanding of mediating and moderating factors. Government interventions, stakeholder engagement, market dynamics, and consumer demand all interact in shaping outcomes (Haryani et al., 2024; Saleh et al., 2023; Zheng & Zeng, 2023). For example, studies have shown that in regions where consumer awareness of climate change is high, SMEs are more likely to align their energy strategies with sustainability goals (Khalid et al., 2021; CR & John, 2024). Similarly, firms that are digitally mature or IoT-enabled are better positioned to leverage smart energy solutions (Alshahrani et al., 2024; Sitompul et al., 2024). Given the increasing urgency to transition to cleaner energy systems and the strategic importance of SMEs in global economic structures, this study aims to conduct a systematic literature review (SLR) to synthesize current knowledge on renewable energy adoption among SMEs. Specifically, the review seeks to identify the drivers, barriers, enablers, and outcomes of adoption, while offering a critical appraisal of existing research gaps and future directions. By consolidating fragmented insights across regions, disciplines, and methodological approaches, this study provides a comprehensive framework to inform policy-making, academic inquiry, and practical implementation.

2. Methodology

To ensure a systematic and objective synthesis of existing knowledge, this study adopts the Systematic Literature Review (SLR) methodology, which has become a standard approach in energy and sustainability research for aggregating fragmented findings across multiple studies. Following best practices outlined by Tranfield et al. (2003), and aligned with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework, the review was designed to ensure transparency, replicability, and methodological rigor throughout the evidence collection and analysis process. The review was guided by four core research questions. First, it sought to identify the main drivers and benefits influencing the adoption of renewable energy technologies (RETs) by small and

medium-sized enterprises (SMEs). Second, it explored the barriers and constraints faced by these firms in transitioning to clean energy solutions. Third, it examined the role of enabling mechanisms such as financial incentives, government policies, and technological readiness in shaping adoption behaviors. Finally, the review aimed to uncover research gaps and provide a roadmap for future scholarly inquiry into this critical area.

A comprehensive search strategy was developed to capture relevant academic literature across major databases including Scopus, Web of Science, Google Scholar, ScienceDirect, and IEEE Xplore. The search terms combined multiple keywords using Boolean operators to ensure a wide and inclusive range of studies. The core search terms included phrases such as: "renewable energy" OR "green energy", AND "SMEs" OR "small and medium enterprises", AND "adoption" OR "implementation" OR "barriers" OR "drivers". This allowed the review to target literature focusing on both the strategic and operational dimensions of renewable energy use within SME contexts. To refine the selection and ensure relevance, specific inclusion and exclusion criteria were applied. Studies were included if they (i) were published between 2014 and 2025, (ii) focused explicitly on renewable energy adoption or integration within SMEs, (iii) were peer-reviewed journal articles or systematic reviews, and (iv) provided empirical data or conceptual frameworks addressing adoption, barriers, or enablers. Conversely, studies were excluded if they (i) were not written in English, (ii) lacked a focus on SMEs, (iii) did not address renewable energy adoption specifically, or (iv) were limited to non-peer-reviewed sources such as opinion pieces, editorials, or conference abstracts without full texts.

After applying these criteria and removing duplicates, an initial pool of studies was narrowed through a multi-stage screening process. Titles and abstracts were first assessed to determine preliminary relevance. This was followed by full-text reviews to evaluate alignment with the research objectives and methodological quality. Through this process, a total of 43 studies were selected for final inclusion in the systematic analysis. These studies span a range of geographic contexts, including developing regions such as sub-Saharan Africa, South Asia, and the Middle East (e.g., Gitone, 2014; Al Naimat & Liang, 2023; Ofori et al., 2022), as well as developed economies like the EU and the U.S. (e.g., Horky & Fidrmuc, 2024; Rahbauer et al., 2016), offering a rich, comparative basis for synthesis. A structured data extraction template was used to collect consistent information from each study, including author(s), year of publication, country or region of focus, type of renewable energy technologies examined (e.g., solar, wind, bioenergy), research design (qualitative, quantitative, or mixed-methods), and the main findings concerning adoption drivers, barriers, and mediating factors. This template enabled the categorization of literature across thematic axes such as economic incentives, technological capabilities, regulatory frameworks, and organizational behavior (e.g., Awamleh et al., 2025; Alshahrani et al., 2024; Behabtu et al., 2020). In keeping with SLR standards, the synthesis of the extracted data was conducted through thematic analysis, allowing for the identification of cross-cutting patterns, contradictions, and knowledge gaps. This analytical process was not merely descriptive but interpretive, focusing on how different studies converge or diverge in their explanations of renewable energy adoption in SMEs. The results of this synthesis are presented in the following sections, organized around dominant themes including financial barriers, technological readiness, policy interventions, and environmental awareness (e.g., Hamed et al., 2023; Hassan et al., 2024; Sobar, 2025).

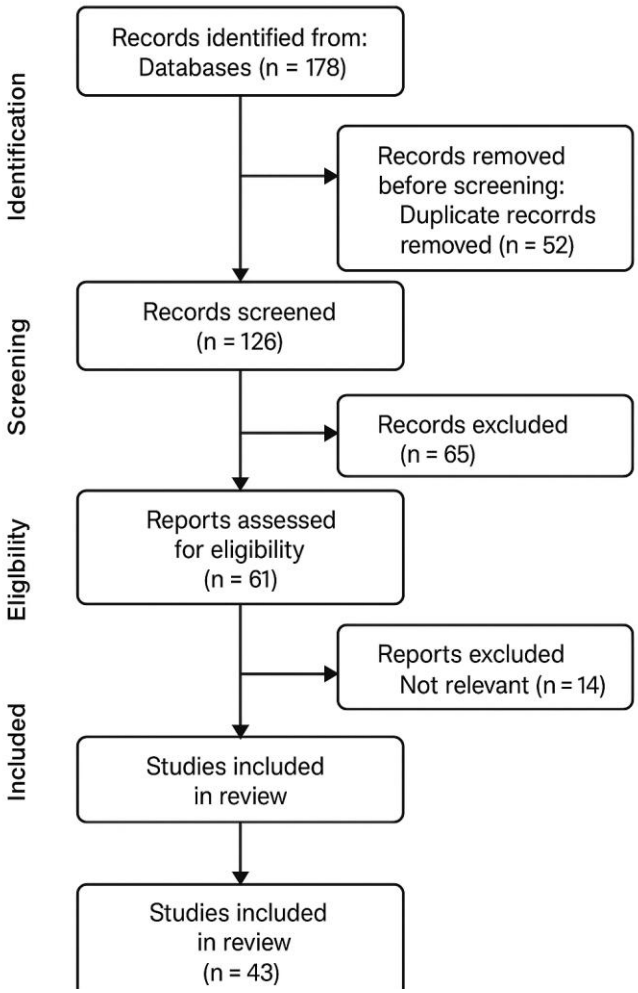

Fig.1: The Systematic Review Process

3. Renewable Energy Adoption among SMEs

The adoption of renewable energy (RE) within the small and medium-sized enterprise (SME) sector has become a crucial element in the global pursuit of sustainable development, energy resilience, and carbon neutrality. SMEs are vital economic contributors worldwide, accounting for the majority of businesses and employment in both developed and developing economies. However, their integration into the green energy transition remains inconsistent and complex, influenced by a range of internal and external variables. This section discusses the landscape of RE adoption in SMEs through a detailed exploration of its prevalence, strategic motivations, sectoral variation, and global context.

3.1 The Role of SMEs in Energy Transition

Small and medium-sized enterprises (SMEs) occupy a pivotal position in the global energy transition due to their scale, economic impact, and cumulative environmental footprint. Representing over 90% of businesses worldwide and generating more than half of global employment, SMEs play an indispensable

role in shaping national and regional development trajectories (Martins et al., 2022). While discussions about decarbonization and energy innovation often focus on large corporations and utilities, the contribution of SMEs to greenhouse gas (GHG) emissions and their potential for clean energy transformation are increasingly gaining recognition (Adanma & Ogunbiyi, 2024). SMEs operate across diverse sectors, ranging from manufacturing and construction to agriculture and services, many of which are energy-intensive and heavily reliant on fossil fuels. Consequently, their energy consumption collectively accounts for a considerable portion of industrial emissions (Sitompul et al., 2024). Given their sheer numbers and widespread geographic presence, SMEs are uniquely positioned to support decentralized renewable energy (RE) deployment. In regions with weak grid infrastructure or unstable electricity supply, particularly in parts of Africa, Asia, and the Middle East, SMEs are not just participants but essential drivers of bottom-up energy transformation (Gitone, 2014; Al Naimat & Liang, 2023).

Importantly, SMEs also face distinct challenges and decision-making processes that differentiate them from large enterprises in terms of energy adoption behavior. Unlike large corporations, which may have dedicated sustainability teams, SMEs often lack the internal capacity, financial flexibility, or technical expertise to proactively invest in clean energy solutions (Meijer et al., 2019). This resource constraint, however, is often accompanied by greater agility, faster decision-making, and local embeddedness, traits that can support innovation and responsiveness to emerging technologies, especially when paired with enabling policy and financial environments (Behabtu et al., 2020; Sobar, 2025). The role of SMEs in the energy transition extends beyond passive adoption. Many SMEs have emerged as innovators, solution providers, and market shapers within the renewable energy ecosystem. For instance, SMEs in the clean-tech sector are developing localized solar technologies, energy management systems, and bioenergy applications that are tailored to the needs of rural communities and low-income users (Alshahrani et al., 2024; Sudarsan et al., 2023). Their proximity to customers and their ability to tailor solutions for niche markets allow them to bridge gaps left by larger players, especially in underserved or remote regions (Hassan et al., 2024).

Furthermore, SMEs contribute to the localization and democratization of energy systems. By investing in small-scale renewable infrastructure, such as rooftop solar panels, mini-grids, and biomass digesters, SMEs reduce dependence on centralized fossil-fuel-based energy and promote energy sovereignty at the community level (Ofori et al., 2022; Awamleh et al., 2025). In this way, they contribute not only to national climate targets but also to inclusive economic development and energy equity. From a policy perspective, recognizing the centrality of SMEs in the energy transition is critical. Governments and international organizations are increasingly incorporating SME-specific provisions in their national energy and climate policies, recognizing their dual role as energy consumers and change agents (Oosthuizen & Inglesi-Lotz, 2022; Hamed et al., 2023). Supportive policy instruments, including subsidies, training programs, and access to finance, are essential to unlocking their full potential. Moreover, embedding SMEs in green supply chains, public procurement policies, and innovation networks can significantly amplify their contributions to clean energy transitions.

3.2 Strategic Motivations for Adoption

The decision of SMEs to adopt renewable energy technologies is rarely based on a single factor. Instead, it emerges from a strategic interplay of economic, environmental, regulatory, and reputational motivations. These motivations often reflect a firm's resource base, market orientation, industry sector, and leadership priorities. Understanding these strategic drivers is essential for policymakers and practitioners aiming to increase renewable energy uptake in the SME sector.

3.2.1 Economic and Operational Efficiency

One of the most frequently cited strategic motivations is the pursuit of cost efficiency. SMEs often operate under tight budget constraints and are highly sensitive to operational costs. Renewable energy technologies, particularly solar PV systems, offer the potential for substantial reductions in energy bills and decreased reliance on volatile fossil fuel markets (Atchike et al., 2022; Ofori et al., 2022). In regions with high electricity tariffs or inconsistent energy supply, such as many parts of sub-Saharan Africa and South Asia, renewables provide a reliable and cost-effective alternative (Al Naimat & Liang, 2023; Gitone, 2014). Over time, the decreasing capital costs of renewable technologies, coupled with the availability of modular and scalable solutions, have made them more accessible to smaller businesses. SMEs adopting these systems can achieve a faster return on investment, particularly when combined with energy efficiency upgrades and digital monitoring tools (Sudarsan et al., 2023; Alshahrani et al., 2024).

3.2.2 Corporate Sustainability and Brand Positioning

Beyond economics, many SMEs are motivated by the opportunity to strengthen their corporate sustainability profile. Firms that adopt renewable energy demonstrate a commitment to environmental responsibility, which can enhance their brand image, attract eco-conscious customers, and improve relationships with stakeholders (Khalid et al., 2021; CR & John, 2024). In some cases, renewable energy adoption is part of a broader Environmental, Social, and Governance (ESG) strategy, particularly in sectors where green credentials are linked to competitive advantage (Zhang et al., 2021; Awamleh et al., 2025). This reputational motivation is especially relevant for SMEs involved in global supply chains, where larger partners may impose sustainability standards as procurement conditions. For such SMEs, renewable energy adoption becomes not only a value-driven choice but also a strategic necessity for market access and long-term viability (Kylili et al., 2025; Sobar, 2025).

3.2.3 Regulatory Anticipation and Compliance

In jurisdictions where climate and energy regulations are advancing, SMEs adopt renewable energy technologies as a proactive compliance strategy. Anticipating stricter environmental laws or mandatory emissions reporting, some firms seek to reduce their carbon footprint early to avoid future penalties or regulatory shocks (Painuly & Wohlgemuth, 2021; Hamed et al., 2023). Furthermore, renewable energy investments can help SMEs qualify for tax credits, green procurement programs, or government-backed certifications that improve their competitive positioning (Oosthuizen & Inglesi-Lotz, 2022; Saleh et al., 2023). While not all SMEs are driven by formal compliance concerns, many are influenced by the policy signaling effect, that is, government communication of future energy plans and sustainability targets shapes SME perceptions of risk and opportunity in the energy market (Mustapha et al., 2025; Haryani et al., 2024).

3.2.4 Innovation and First-Mover Advantage

A smaller but significant group of SMEs view renewable energy adoption as part of a strategic innovation strategy. These firms see clean energy not just as a cost-saving tool but as an enabler of new business models, product differentiation, and service innovation (Meijer et al., 2019; Sitompul et al., 2024). In some sectors, early adoption of RE systems has enabled SMEs to position themselves as sustainability

leaders, capturing niche markets and benefiting from media visibility and award recognition. In technology-driven environments, SMEs with R&D capacity or links to universities and incubators may engage in co-developing renewable solutions, including microgrids, smart energy management tools, or hybrid systems (Behabtu et al., 2020; Alshahrani et al., 2024). This approach not only supports internal sustainability but also creates opportunities for revenue generation through consulting or energy service provision.

3.3 Sectoral and Geographic Variability

The adoption of renewable energy (RE) technologies among SMEs is far from uniform. It varies significantly across sectors and geographic regions due to differences in energy intensity, market maturity, policy frameworks, and access to finance and technology. Understanding these variations is critical to designing targeted strategies that can accelerate adoption and address context-specific barriers.

3.3.1 Sectoral Differences in Energy Demand and Application

Different sectors have varying energy profiles, which influence the feasibility and attractiveness of RE investments. Manufacturing, agriculture, construction, and food processing SMEs tend to have higher energy demands, making renewable energy adoption more cost-effective and urgent in these sectors (Behabtu et al., 2020; Sitompul et al., 2024). For instance, SMEs involved in agro-processing often require continuous electricity for refrigeration and milling, needs that can be reliably met through solar hybrid systems or biogas (Ofori et al., 2022). On the other hand, service-based SMEs, such as those in retail, education, or hospitality, may have more intermittent or lower energy needs. While this can reduce the immediate cost-saving impact of RE adoption, these firms often adopt renewable energy for reputational reasons or to align with sustainability goals of their customers and partners (CR & John, 2024; Awamleh et al., 2025). In the hospitality industry, for example, green certifications and visible RE installations can enhance a business's market appeal. Additionally, IT and digital firms with high server and computing loads may pursue RE adoption both as a sustainability strategy and as a way to manage operational risks from power outages (Alshahrani et al., 2024). Thus, sector-specific drivers influence both the decision to adopt and the type of technology chosen.

3.3.2 Regional and Country-Level Variation

Geographic variation is another significant determinant of RE adoption among SMEs. In developed economies, such as those in the European Union, the United States, and parts of East Asia, SMEs benefit from mature renewable energy markets, extensive policy support, and well-established financing mechanisms (Horky & Fidrmuc, 2024; Segarra-Blasco & Jove-Llopis, 2019). These contexts enable SMEs to access green loans, tax incentives, and technical expertise with relative ease. In contrast, developing economies often present a dual reality. On one hand, weak grid infrastructure, high energy tariffs, and erratic power supply push SMEs to seek alternatives, making RE adoption more of a necessity than a strategic choice (Gitone, 2014; Al Naimat & Liang, 2023). On the other hand, these same regions face challenges such as limited access to capital, low awareness of RE technologies, and bureaucratic delays that can hinder adoption (Obuseh et al., 2025; Mustapha et al., 2025).

For example, in sub-Saharan Africa, SMEs have been at the forefront of decentralized solar energy adoption due to chronic energy access challenges. In Kenya, the proliferation of pay-as-you-go (PAYG) solar services has enabled even micro-enterprises to power their operations with renewable sources (Gitone, 2014). In Middle Eastern contexts like Jordan and Palestine, political support combined with

high solar potential has created momentum for adoption, particularly in industrial parks and energy-intensive sectors (Hamed et al., 2023; Saleh et al., 2023). Meanwhile, in Southeast Asia, government-led energy diversification strategies and climate commitments have led to growing interest among SMEs in solar and small hydro technologies (Zheng & Zeng, 2023). In some areas, community-based renewable energy initiatives have empowered rural SMEs to co-invest in shared infrastructure (Sudarsan et al., 2023).

3.3.3 Influence of Local Ecosystems and Infrastructure

Local innovation ecosystems, availability of technical support, and infrastructure also influence the pace and scale of adoption. SMEs situated in urban centers or industrial clusters often have greater access to energy consultants, installation firms, and peer learning networks (Avwioroko & Ibegbulam, 2024). These clusters create economies of scale and reduce transaction costs, which can accelerate collective adoption. By contrast, rural SMEs may be limited by poor logistical networks, unreliable technology supply chains, and inadequate after-sales services. These structural disadvantages can increase the perceived risk of RE adoption, especially in the absence of local demonstrations or case studies (Zhindon-Almeida & Ruiz-Carrillo, 2025).

4. Thematic Findings

The analysis of the 43 selected studies reveals that the adoption of renewable energy (RE) by SMEs is shaped by a complex interplay of motivations, challenges, and contextual influences. To provide a comprehensive understanding of these dynamics, the findings are organized into three core themes: (1) drivers, which encourage and enable adoption; (2) barriers, which hinder or delay action; and (3) mediating and moderating factors, which influence how SMEs perceive and respond to opportunities and constraints. Together, these themes offer critical insights into the behavioral, institutional, and systemic forces at work in the renewable energy transition for SMEs.

4.1 Drivers of Renewable Energy Adoption

The reviewed literature identifies a variety of economic, environmental, policy-based, and organizational factors that serve as catalysts for RE adoption among SMEs.

4.1.1 Cost Savings and Energy Independence

One of the most prominent drivers is the potential for long-term cost savings. Renewable technologies, especially solar photovoltaics (PV), offer SMEs a way to reduce dependence on grid electricity and fossil fuel inputs, which are often subject to volatile pricing and inconsistent supply (Adanma & Ogunbiyi, 2024; Atchike et al., 2022). In developing countries with unreliable energy infrastructure, SMEs that adopt solar or hybrid RE systems gain access to more stable and self-reliant energy sources, which improves productivity and business continuity (Al Naimat & Liang, 2023; Gitone, 2014). Furthermore, studies show that RE adoption can lead to substantial reductions in operational expenses over time. Though the initial capital investment can be high, many SMEs consider it worthwhile when viewed from a lifecycle cost perspective (Ofori et al., 2022). Some firms report breaking even within three to five years, particularly when energy prices are high or escalating (Behabtu et al., 2020).

4.1.2 Sustainability and Corporate Social Responsibility (CSR)

Another significant motivator is the desire to enhance the firm's environmental credentials and align with

corporate social responsibility (CSR) objectives. As global awareness of climate change and sustainability grows, many SMEs recognize that adopting clean energy practices can enhance their reputation, customer loyalty, and brand value (Khalid et al., 2021; CR & John, 2024). In some cases, sustainability becomes a key part of the firm's identity and value proposition, especially in sectors where green branding offers a competitive edge. Studies also highlight the importance of external pressure from stakeholders. SMEs that serve environmentally conscious consumers, supply chains with sustainability criteria, or investors with ESG requirements are more likely to adopt renewable energy technologies to meet expectations and secure long-term business relationships (Zhang et al., 2021; Awamleh et al., 2025).

4.1.3 Policy Incentives and Financial Support

Government support, in the form of policy incentives and financial instruments, is a well-documented driver. Instruments such as tax incentives, feed-in tariffs, grants, green financing, and subsidies help reduce the upfront cost barrier and enhance the economic viability of RE investments (Hamed et al., 2023; Oosthuizen & Inglesi-Lotz, 2022). In Jordan, for example, industrial SMEs were significantly more likely to adopt solar power when they had access to subsidized loans and predictable policy frameworks (Saleh et al., 2023). Importantly, it is not just the existence of these incentives that matters, but also their accessibility, clarity, and reliability. Studies show that well-publicized, easy-to-apply programs are more effective in stimulating adoption than complex, bureaucratic, or inconsistently enforced policies (Mustapha et al., 2025; Haryani et al., 2024).

4.1.4 Technological Readiness and Innovation

The internal capacity of SMEs to adopt and integrate renewable energy is also shaped by their technological orientation and innovation culture. Firms that are digitally mature or already using IoT-based solutions, energy monitoring systems, or smart-grid integration are more likely to perceive RE technologies as compatible and beneficial (Alshahrani et al., 2024). Additionally, SMEs involved in R&D, or those embedded in innovation ecosystems, often view RE adoption as part of their broader growth or transformation strategies (Meijer et al., 2019; Sitompul et al., 2024).

4.2 Barriers to Renewable Energy Adoption

While the benefits of RE adoption are clear, many SMEs face substantial hurdles that delay or prevent implementation. These barriers are not only financial but also informational, institutional, and technical in nature.

4.2.1 Financial Constraints and High Upfront Costs

Across all regions, the high initial capital expenditure associated with renewable energy systems remains the most consistent barrier (Luthra et al., 2015; Obuseh et al., 2025). Many SMEs operate on tight budgets and are unable or unwilling to allocate funds to long-term infrastructure projects, even if the payoff is positive over time. Lack of collateral, credit history, or access to green financing further exacerbates this challenge (Bugwandin et al., 2025; Horky & Fidrmuc, 2024). Even when financial assistance is available, studies report that SMEs often lack the financial literacy or administrative capacity to navigate loan or subsidy applications, especially in developing countries (Twumasi et al., 2022; Ogunyemi & Ishola, 2024).

4.2.2 Knowledge Gaps and Perceived Complexity

A significant portion of SMEs lack adequate information, technical knowledge, and awareness of the benefits and workings of RE systems (Khalid et al., 2021; Sudarsan et al., 2023). This creates uncertainty about return on investment, reliability, maintenance needs, and supplier credibility. In many cases, misinformation or outdated perceptions discourage firms from exploring RE options altogether. Studies also find that perceived technical complexity, such as integrating RE into existing systems or handling after-sales service, discourages adoption, especially in non-tech sectors or firms without technical staff (CR & John, 2024; Gitone, 2014).

4.2.3 Policy Ambiguity and Institutional Gaps

While supportive policies exist in many regions, regulatory inconsistency, bureaucratic delays, and lack of coordination among government agencies undermine their effectiveness (Painuly & Wohlgemuth, 2021; Mustapha et al., 2025). SMEs often express skepticism regarding the stability of subsidies or concern that policy changes will make their investments obsolete. Moreover, insufficient enforcement and oversight can lead to market failures, such as poor-quality equipment, unlicensed providers, and fraud, which further erode trust in the system (Zhindon-Almeida & Ruiz-Carrillo, 2025).

4.2.4 Infrastructure, Maintenance, and Ecosystem Constraints

A lack of local technical capacity, repair services, and trusted suppliers creates additional friction in many low-income or rural regions (Zheng & Zeng, 2023; Behabtu et al., 2020). In areas without access to certified installers or spare parts, SMEs face the prospect of being stranded with malfunctioning systems. This barrier is especially pronounced in geographically isolated communities, where poor transport and communication infrastructure further complicate system deployment and maintenance (Alshahrani et al., 2024).

4.3 Mediating and Moderating Factors

Beyond drivers and barriers, several studies identify variables that influence the strength or direction of the adoption process. These mediating and moderating factors help explain why some SMEs adopt RE successfully while others with similar profiles do not.

4.3.1 Government as a Systemic Enabler

In contexts where governments act not only as funders but also as facilitators of knowledge, partnerships, and capacity building, SMEs are more likely to adopt renewable energy (Haryani et al., 2024; Saleh et al., 2023). Public-private partnerships, training initiatives, and awareness campaigns often serve to bridge the gap between policy and practical implementation. Governments can also act as signalers of legitimacy, especially in early-stage markets, where uncertainty and risk aversion are high (Mustapha et al., 2025).

4.3.2 Organizational Culture and Strategic Vision

SMEs with strong internal leadership and a sustainability-oriented culture are better positioned to navigate external constraints and prioritize renewable energy investments (Sobar, 2025; Awamleh et al., 2025). Studies highlight that personal values of owners and managers play a major role in shaping adoption decisions, especially in founder-led firms. In contrast, SMEs focused solely on short-term

financial performance, or those lacking innovation capacity, may resist change even when incentives are available.

4.3.3 Sectoral Exposure and Market Pressures

The regulatory and market environments of specific sectors also moderate adoption behavior. SMEs in export sectors, food and agriculture, or manufacturing are more likely to face external sustainability requirements, prompting earlier and more robust RE adoption (Kylili et al., 2025). Local service firms may face fewer pressures and thus adopt at a slower pace.

4.3.4 Role of Third-Party Stakeholders

Finally, the involvement of consultants, NGOs, ESCOs, and technology providers can mediate both the financial and knowledge barriers by providing support services, feasibility studies, and implementation expertise (Avwioroko & Ibegbulam, 2024; Alshahrani et al., 2024). These third parties often act as intermediaries between SMEs and government programs, reducing risk and facilitating adoption.

5. Discussion

The systematic review of 43 studies has revealed that renewable energy (RE) adoption among SMEs is influenced by a diverse set of motivations, constraints, and contextual factors. The following discussion section interprets these thematic findings, integrates them with existing theoretical frameworks, and outlines implications for both policy and practice. It also identifies research gaps that must be addressed to foster a more inclusive and scalable transition to renewable energy in the SME sector.

5.1 Synthesis of Key Findings

The adoption of RE by SMEs is not merely a matter of technical feasibility or financial calculation, it reflects a complex interplay between internal firm characteristics and external systemic influences. Economic motivations, such as reducing long-term energy costs and achieving independence from unstable electricity grids, are widely reported across various geographic contexts (Adanma & Ogunbiyi, 2024; Ofori et al., 2022). However, these financial drivers are often tempered by significant upfront costs and limited access to credit, which serve as deterrents, particularly for micro and small enterprises in developing regions (Luthra et al., 2015; Obuseh et al., 2025). At the same time, the strategic alignment of RE adoption with corporate sustainability goals is becoming increasingly influential, especially among SMEs engaged in international markets or subject to environmental regulations. Many firms adopt renewable energy technologies not only to enhance their environmental performance but also to improve their brand reputation, meet buyer standards, and appeal to environmentally conscious consumers (Khalid et al., 2021; Awamleh et al., 2025). In these cases, RE adoption serves both a functional and symbolic purpose.

What emerges from this synthesis is that no single factor acts in isolation. Successful adoption often requires the convergence of favorable economic conditions, institutional support, leadership commitment, and access to knowledge and technical expertise. For instance, in Jordan, SMEs benefited from not only policy incentives but also targeted training programs and public-private partnerships, which together enabled a higher rate of adoption (Hamed et al., 2023; Saleh et al., 2023). This suggests that multi-pronged interventions, rather than isolated measures, are more effective in fostering adoption.

5.2 Theoretical Contributions

This review contributes to the theoretical literature on sustainability transitions, innovation adoption, and SME behavior by reinforcing and extending several important concepts. First, the findings support the multi-level perspective (MLP) on socio-technical transitions, which argues that changes in technology adoption occur at the intersection of niche innovations (e.g., RE technologies), socio-economic regimes (e.g., energy markets), and macro-level landscapes (e.g., climate policy, global sustainability norms). SMEs interact with all three levels, and their adoption choices are shaped by both top-down (policy, regulation) and bottom-up (firm capacity, community engagement) pressures (Painuly & Wohlgemuth, 2021; Mustapha et al., 2025).

Second, the review expands the application of behavioral and institutional theories to the context of SMEs. It reveals that RE adoption is not purely a rational economic decision but also reflects normative influences, legitimacy concerns, and the personal values of firm leaders (Sobar, 2025; Meijer et al., 2019). This supports earlier research suggesting that SMEs are more likely to adopt sustainable practices when they are embedded in social networks or guided by mission-driven leadership. Third, the dual role of barriers and enablers as both outcomes and inputs suggests a need to move beyond linear adoption models. Many contextual variables, such as government policy, stakeholder pressure, or availability of consulting support, can function as mediators or moderators, enhancing or dampening the impact of traditional drivers and constraints. This complexity calls for more dynamic, integrative frameworks that accommodate feedback loops and contextual heterogeneity (Haryani et al., 2024; Avwioroko & Ibegbulam, 2024).

5.3 Policy and Practice Implications

For policymakers, the findings underscore that interventions must be both targeted and systemic. Offering subsidies or feed-in tariffs alone is insufficient if SMEs cannot access them due to complex application procedures, lack of awareness, or insufficient technical knowledge. Therefore, financial incentives must be complemented by outreach efforts, technical assistance, and institutional support that address SMEs' capacity limitations (Oosthuizen & Inglesi-Lotz, 2022; Sudarsan et al., 2023). In contexts where energy infrastructure is weak, the adoption of decentralized RE systems by SMEs can serve as a tool for local development and energy equity. In such cases, governments and development agencies should prioritize investment in shared infrastructure, such as mini-grids or local repair networks, and support the emergence of service providers who can cater to SMEs (Behabtu et al., 2020; Zhindon-Almeida & Ruiz-Carrillo, 2025).

SMEs themselves should be encouraged to view RE adoption not only as a compliance measure or cost-cutting strategy but also as a long-term strategic investment. Firms that integrate renewable energy into their core operations often experience broader benefits, including improved risk management, innovation capability, and access to sustainability-oriented markets (Kylili et al., 2025; Sitompul et al., 2024). Entrepreneurial ecosystems, including incubators, financial institutions, and trade associations, have a vital role to play in helping SMEs recognize and capitalize on these benefits. Moreover, policy initiatives should leverage intermediary organizations, such as energy service companies (ESCOs), technical consultants, and local NGOs, to act as bridging agents between SMEs and the complex world of renewable energy technology and finance (Alshahrani et al., 2024; Saleh et al., 2023). These actors can help de-risk investment decisions by providing tailored feasibility studies, installation services, and capacity building.

5.4 Research Gaps and Future Directions

While this review offers valuable insights, it also reveals significant gaps in the literature that should be addressed in future studies. First, most existing research is cross-sectional, limiting our ability to understand how adoption evolves over time. There is a need for longitudinal studies that track SME behavior across different stages of the adoption process and in response to policy changes or economic shocks (Mustapha et al., 2025). Second, the literature is geographically skewed toward a few middle-income and high-income countries. Underrepresented regions, such as Latin America, Central Asia, and small island developing states, remain poorly studied. Comparative studies across different regulatory regimes and energy access conditions could yield new insights into context-specific adoption models (Obuseh et al., 2025; Gitone, 2014). Third, the influence of firm-level characteristics, such as age, size, gender composition of leadership, and ownership structure, is not yet well understood. Future studies should investigate how these factors influence risk perception, investment capacity, and sustainability orientation. For instance, are younger SMEs more willing to experiment with RE? Do women-led businesses adopt RE at higher or lower rates? Finally, scholars should explore how emerging technologies, such as blockchain, AI-based energy management, and carbon tracking tools, might intersect with SME renewable energy strategies. Interdisciplinary research that bridges energy studies with organizational behavior, digital innovation, and behavioral economics will be crucial to advancing theory and practice in this space.

6. Conclusion and Future Research Agenda

The growing urgency of climate change, rising energy costs, and the global push toward sustainable development have placed renewable energy (RE) adoption by small and medium-sized enterprises (SMEs) at the forefront of the clean energy transition. This systematic literature review synthesized findings from 43 peer-reviewed studies published between 2014 and 2025 to explore the motivations, challenges, and contextual influences that shape SME behavior regarding renewable energy technologies. The review revealed that while SMEs across various sectors and regions are increasingly aware of the benefits of renewable energy, such as long-term cost savings, operational resilience, and sustainability branding, widespread adoption remains uneven. Key drivers include economic incentives, environmental responsibility, stakeholder pressure, and regulatory compliance. However, these are often offset by barriers such as limited financial capacity, lack of technical expertise, policy ambiguity, and infrastructural limitations. Importantly, a set of mediating and moderating factors, including government intervention, organizational culture, and the role of intermediaries, significantly influence the adoption process.

This study underscores that RE adoption among SMEs is not solely a technical or economic decision, but a strategic and socially embedded process shaped by multi-level interactions between firms, institutions, and markets. It calls for a more integrated approach, where policy incentives, capacity-building efforts, and ecosystem support are designed in tandem to unlock the full potential of SMEs in the energy transition. From a practical standpoint, governments and development agencies must adopt SME-specific energy policies that address their unique constraints and leverage their agility. Financial support mechanisms need to be complemented by awareness campaigns, simplified application processes, and partnerships with third-party actors such as energy consultants and local NGOs. SMEs, in turn, should be encouraged to view renewable energy not just as a utility expense, but as a strategic asset, one that aligns with broader goals of resilience, innovation, and market differentiation. From a research perspective, several gaps offer promising avenues for future exploration. First, longitudinal studies are

needed to understand how SME energy strategies evolve over time. Second, more attention must be paid to geographic diversity, particularly underrepresented regions and rural economies. Third, research should investigate intersectional firm characteristics, such as the role of gender, ownership structure, and generational leadership in shaping adoption behavior. Finally, future work should explore the potential of emerging technologies, like AI, IoT, and blockchain, in enabling more flexible and efficient renewable energy systems for SMEs.

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