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ENERGY MANAGEMENT IN SMALL AND MEDIUM ENTERPRISES: SCIENTOMETRIC ANALYSIS OF THE CURRENT EVOLUTION OF THE RESEARCH FIELD.

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Abstract: *Small and medium-sized enterprises (SMEs) are crucial in advancing sustainability objectives. This paper contributes to the understanding of energy management in SMEs by considering the impact of contemporary developments. A systematic analysis of 45 articles from the Web of Science database maps the evolution of this field over the last five years. Since 2020, post-pandemic adaptation, stricter climate policies such as China's dual-carbon initiative, and the rapid integration of artificial intelligence, big data, and smart technologies have influenced the research agenda. Consequently, the urgency for SMEs to adopt sustainable practices has intensified, defining this period as a decisive stage in climate policy execution and technological transformation. Findings describe current methods of energy management and sustainable performance in SMEs.*

Key words: *Scientometric analysis, small and medium enterprises, Energy Management, Sustainability.*

1. INTRODUCTION

"Small and Medium-sized Enterprises (SMEs) represents a central foundation of global economies, influencing significantly to employment and innovation, both key drivers of the green and digital transformation to compete in global and local market" [1].

Small and medium sized enterprises account for approximately 99% of all business worldwide, their total energy use or demand are considerable for the European Union, positioning them as a key element in research on climate objectives [2].

Energy management in SMEs is shaped by their unique efficiency potential, the drivers or barriers they encounter, and the policy frameworks recommended. Prior studies such us as those by Ozbugday et al. [3] and Dolšak et al. [4] show case these aspects.

However, the field is broad, understanding its evolution requires mapping the integration of sustainability and new technologies. Scientometric methods offer a valuable tool for this challenge by revealing trends in scientific production. Its application employed in other such as the work of Yan & Zhiping [5], highlights its value. In this context, the present study conducts co-occurrence analysis and bibliographic coupling of publications retrieved from the Web of Science database. Although the relevance of SMEs in energy transitions the scientometric study of energy management in this context remains limited. Earlier research focused on general energy management and sustainability issues, overlooking SMEs' particular traits and barriers.

According to Palm and Backman [6], beyond these common constraints, many programs fail because of weak communication and one-directional knowledge transfer. According to Gennitsaris et al., [2] policy inconsistencies and insufficient support are key barriers, while Ketenci and Wolf [7] add that analytical tools and standards are inadequately adjusted to SMEs contexts, particularly in non-energy-intensive sectors.

Collectively, these studies suggest that resolving the limited attention to SMEs in energy management depends on customized methodologies, stronger communication

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practices and policies and financial support specific to SMEs.

The examined timeframe holds particularly relevance: since 2020, the research agenda have been driven by post-pandemic adaptation (Aljohani et al., 2025) [8], the enforcement of climate strategies such as China's dual carbon goals (Jia et al., 2025) [9], and the digitalization of industry through big data, smart technologies and artificial intelligence (Jia et al., 2025) [9]. By highlighting the evolution of the field, this study offers a novel and timely perspective to academic discourse.

2. RESEARCH METHODOLOGY

The Web of Science database was selected as the data source. The choice of Web of Science is justified as it covers the literature and sources, offering data analysis and visualization tools relevant to interdisciplinary topics like energy management in SMEs [6]. The search string used was TITLE-ABS-KEY ("Energy Management") AND TITLE-ABS-KEY ("SMEs"). Based on prior studies and multiple trials, the authors opted to keep only the acronym SMEs, which is widely used in literature, since longer terms such as 'small and medium enterprises' or 'small and medium-sized enterprises' may produce irrelevant results and hinder the selection of relevant documents [10]. The research considered only articles, review papers, and conference proceedings published in English within the last five years to guarantee relevance in the field of Energy Management.

The data collection period covered 2020 to May 30, 2025, due to its relevance ensuring that the most current developments in digital transformation and sustainability practices in SMEs were considered. Applying these three criteria, 64 relevant articles were selected and assessed independently. During the eligibility stage, 18 publications were excluded, resulting in a final set of 45 included papers.

Research questions:

The software VOSviewer v.1.6.20 was used for technical assistance in managing data and visualizations, extracting co-occurrence and bibliographic coupling analysis [11].

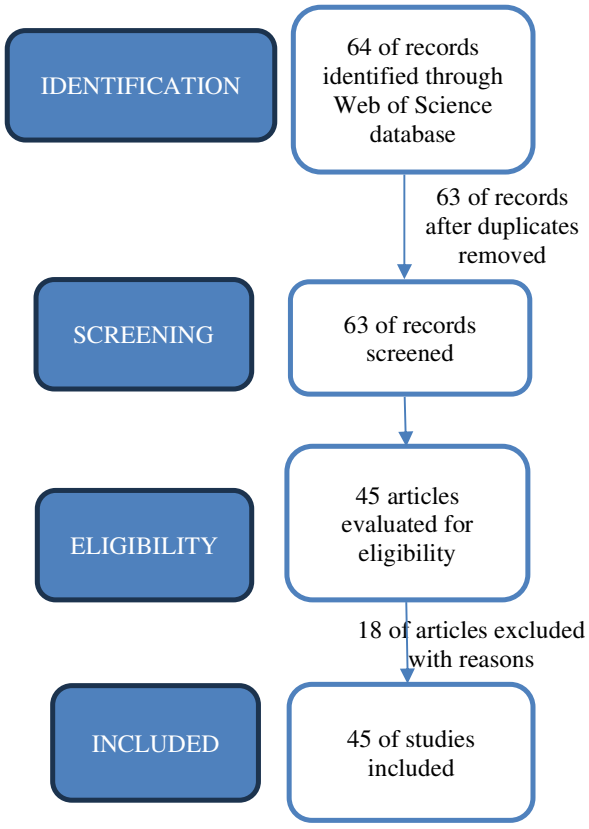

Fig. 1. PRISMA framework diagram indicating the number of articles analyzed in the review.

Research questions:

Q1: What main themes in energy management in SMEs are currently examined in academic research?

Q2: How extensively have issues related to energy management in SMEs been addressed?

Q3: Which gaps and future research avenues remain in the study of energy management in SMEs?

Shown below is the PRISMA framework used in this review, structured in four stages:

3. RESULTS AND DISCUSSIONS

The research utilizes scientometric methods to offer an objective assessment of the Energy Management landscape in SMEs. The use of VOSviewer facilitated the mapping of scientific literature, making it possible to analyze how academic research has been produced, shared, and influenced in this area. Findings from this analysis offer important support to stakeholders

in comprehending the advancements and ongoing obstacles in energy management.

3.1 Clusters descriptions.

The analysis of co-occurrence revealed 45 keywords and their associated research clusters, systematically grouped into six clusters as detailed below:

(1) Strategic Energy Management in SMEs (Red Cluster); (2) Energy Efficiency Policy and SMEs Implementation (Green Cluster); (3) Challenges and Capabilities for Energy Management in SMEs (Blue Cluster); (4) Energy Management Practices and Digital Transformation as a Strategic Investment for Sustainable Development in SMEs (Yellow Cluster); (5) Energy Management Frameworks for Sustainable Firm Performance (Purple Cluster); and (6) Industrial Energy Optimization in SMEs (Light Blue Cluster), as depicted in Fig. 2. Cluster 1 is categorized as Strategic Energy Management in SMEs (Red Cluster). Keywords include determinants, driving forces, energy management, environmental management, growth, impact, implementation, innovation, management practices, performance, and strategy. The cluster centers on strategic approaches to energy management. The designation and keyword inspection indicate that the research mainly concerns drivers, implementation, and performance outcomes in SMEs.

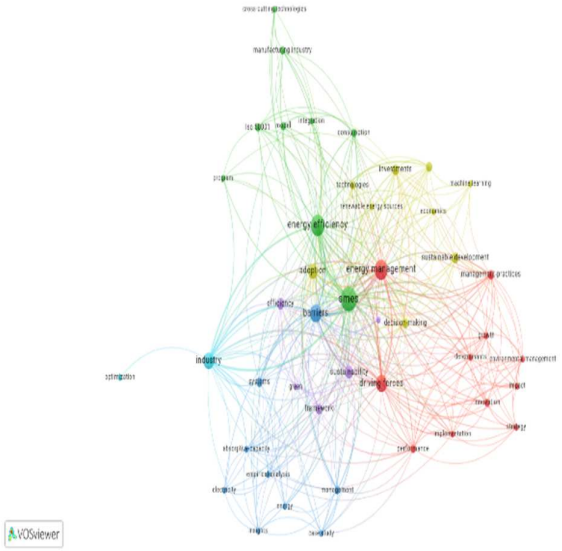

Fig. 2. Clusters based on keywords.

The scope of research goes beyond technical considerations, also exploring the reasons for SMEs' adoption of energy management and the benefits it provides. With the highest frequency and total link strength, energy management stands as the cluster's core subject, guiding all SME discussions. The concept of driving forces is highly significant, indicating extensive research on the economic and regulatory drivers of energy management. Implementation refers to the execution of strategies, while performance highlights the cluster's orientation toward quantifiable outcomes. Terms including management practices and strategy indicate a focus on long-term and comprehensive business planning. Innovation represents fresh approaches, with growth and impacts reinforcing that the benefits go beyond energy savings, affecting the entire organization broadly. The conceptual framework is evident in the robust connections among driving forces, determinants, energy management, as well as strategy and implementation. This suggests that scholars examine how different external and internal drivers shape strategic decisions and practical implementation steps. Furthermore, direct associations from implementation to performance, growth, and impact reflect a research emphasis on measurable outcomes and organizational benefits. The aspects of implementation and driving forces involve management practices and strategy, which serve as mediators between the two terms. This indicates that successful energy management in SMEs is highly contingent on the degree of integration between management practices and the overall organizational strategy. The interconnection within the cluster reflects research mapping the entire lifecycle of the energy management process, from motivation to the realization of benefits.

Cluster 2, labeled the Green Cluster, emphasizes energy efficiency policy and SME implementation. Keywords include consumption, cross-cutting technologies, energy efficiency, integration, ISO 50001, manufacturing industry, model, program, and SMEs. The anchor of this cluster is energy efficiency and SMEs, validated by their centrality and strong relational ties. The strong

link strength of ISO 50001 demonstrates research focus on structured standards providing SMEs with actionable energy management pathways. Additionally, its link with energy efficiency highlights research on how formalized systems drive improvements, suggesting exploration of challenges, adoption, and outcomes of implementing such standards. The direct connection of energy efficiency to consumption signals efforts to cut energy usage, focusing on quantifiable and practical results. The cluster demonstrates the manufacturing industry as a primary sector where SMEs and energy efficiency are explored. The presence of keywords including cross-cutting technologies, integration, model and program, indicate research examining various approaches to efficiency implementation, forming smaller networks within the theme of energy efficiency. Findings suggest the main goal is to improve energy efficiency in organizations through systematic and technological strategies, with measurable benefits like lower consumption, increased competitiveness, and stronger data insights. Such studies deal with common obstacles like turning theoretical estimates of savings into concrete, measurable reductions and applicable actions.

Cluster 3 illustrates that studies not only record problems but also investigate the mechanisms and capacities required to address them, with absorptive capacity and barriers appearing as a reinforcing pair. It suggests a shift in research from simply identifying problems to adopting a more systematic approach that emphasizes the role of organizational dynamics in overcoming difficulties. As a central concept, absorptive capacity mediates between external contributions and real implementation, facilitating the processing and application of information on energy and related barriers. While the benefits of energy management systems are evident for organizations willing to implement them, research emphasizes the difficulties SMEs experience in this process. This contrast between expected advantages and real-world limitations for SMEs points to an essential misalignment. Accordingly, addressing this gap must be a priority for future studies.

Cluster 4 highlights energy management practices and digital transformation as critical strategies for sustainable development in SMEs (Yellow Cluster). Investment and decision-making are central to this thematic cluster, showing high total link strengths of 36 and 35, reinforced by strong interconnections in the network. This suggests that financial considerations play a vital role in energy management choices. The implication is that research within this cluster addresses not only the financial requirements for adoption but also evaluates methods that show the sustained economic benefits of these strategies. Strategic decision making emerges as a key element, with its high link strength emphasizing its importance in the cluster. Research in this field has progressed from basic issues to viewing energy management as a strategic investment. The co-occurrence of machine learning and sustainable development signals the progression toward advanced digital technologies. This theme indicates that research addresses sustainability challenges with innovative financial and technological approaches.

In Cluster 5 Energy Management Frameworks for Sustainable firm performance (Purple Cluster), sustainability stands out as the core focus. The strong associations of this keyword suggest that research is progressing beyond financial measures; moreover, its relationship with firm performance and frameworks implies that these studies examine how integrating sustainable energy practices, often through structured frameworks, can provide a competitive advantage, reflecting a more mature and strategic perspective on sustainability in SMEs' energy management. The use of the term framework indicates that researchers are developing standardized approaches to energy management tailored to SMEs, underlining the structured and methodological nature of work within this cluster. Efficiency is identified as the direct operational aim of energy management. Research discusses efficiency in terms of achieving sustainable results supported by structured frameworks; in contrast to sustainability and frameworks, it is considered a crucial instrument for realizing sustainability goals rather than the ultimate aim. This indicates that operational benefits correspond with long-term environmental and corporate goals. By

placing firm performance next to sustainability and green, the cluster emphasizes that SMEs are motivated by both environmental considerations and concrete financial benefits.

Within the network, the prevalence of the term industry underscores the thematic context and indicates the main area of focus in Cluster 6 Industrial energy optimization in SMEs (Light Blue Cluster). By integrating the concept of optimization, the research highlights the targeted goal within industrial applications. The low values associated with 'optimization' suggest that this cluster primarily identifies and discusses the needs and opportunities for energy optimization in industrial settings, while the absence of energy as an explicit term reflects its implicit presence from the broader field of Energy Management in SMEs. The predominance of 'industry' and the modest but evident role of 'optimization' suggest an initial stage of research prior to detailed implementation studies.

3.2 Cluster Connections:

In addition to mapping research themes, the VOSviewer visualization outlines a roadmap for collaboration aimed at improving SME energy management.

Strategic Energy Management in SMEs (Red Cluster) and Challenges and Capabilities for Energy Management in SMEs (Blue Cluster):
Within the network visualization, the interconnections across the SME energy management research landscape are clearly displayed. The situation can be interpreted as a causal relationship, with barriers and absorptive capacity exerting a strong influence on implementation aspects. The relationship reveals an orientation in the research toward linking problems with their solutions. In this framework, the red cluster identifies necessary outcomes, and the blue cluster determines challenges, suggesting that research is aimed at overcoming obstacles in implementation.

The cluster on 'Energy Management Practices and Digital Transformation as a Strategic Investment for Sustainable Developments in SMEs emphasizes machine learning and renewable energy sources as components of sustainable development, suggesting that these technologies can serve as catalysts for implementing energy management initiatives (Red Cluster). In Cluster One, the driving forces are associated with investments in the Yellow Cluster, highlighting the necessity of economic incentives for effective energy management. The focus on performance, growth, and impact on Cluster One offers a strong foundation to justify such investments for SMEs. The research conducted in this cluster emphasizes both the necessity of investment and the response to economic challenges.

Red Cluster (implementation and performance) and Blue Cluster (barriers and absorptive capacity):

When significant barriers are present, they may require more robust drivers or diminish the effectiveness of those currently operating. Absorptive capacity, discussed in the blue cluster, strongly influences the implementation aspects of the first cluster; for example, overcoming barriers to energy management in SMEs largely depends on this capacity. This link demonstrates a research orientation toward identifying problems and offering solutions.

Purple Cluster (Frameworks, Sustainability, firm Performance) and Green Cluster (Systematic Efficiency, Standards):

The adoption of energy management standards, such as ISO 50001, together with supporting models and programs, creates a foundation for systematic efficiency. Perspectives on efficiency highlight its role as a critical resource for advancing broader sustainability goals, frequently by means of frameworks. This analysis points to an evolution from energy conservation alone to a broader strategic and systemic perspective. The academic focus is shifting towards providing SMEs with systematic and structured approaches. This conclusion arises from the connection identified between the clusters, given their mutual link to performance.

Purple Cluster (Frameworks) and Blue Cluster (Barriers):

The orientation toward resolving problems through this association underscores the obstacles SMEs must overcome in adopting formal management systems. The yellow cluster also identifies barriers such as technological and

financial constraints, implying a knowledge–action gap where research must prioritize the development of scalable and affordable energy management solutions tailored for SMEs.
Light Blue Cluster (Industrial Optimization) and Green Cluster (Energy Efficiency) and red cluster (driving forces):

The connection between the term 'industry' and energy efficiency is central, suggesting that the concept of industry is consistently associated with actions to improve energy efficiency in this research area. The green cluster features terms such as cross-cutting technologies, manufacturing industry, and ISO 50001 that emphasize energy efficiency, while cluster 6 reflects a broader industrial application oriented toward optimization but with weaker links to driving forces, indicating research that identifies the problem without deeply addressing practical approaches or motivational aspects of industrial energy optimization.

Light Blue Cluster (Industrial Optimization) and Blue Cluster (Barriers):

Within this cluster, the discussion evolves from identifying theoretical barriers encountered by enterprises in implementing optimization strategies to a practical grasp of the difficulties that need to be overcome to achieve tangible outcomes. Across clusters, terms such as sustainable development and sustainability stand out as primary outcomes and drivers, highlighting the comprehensive nature of SME energy management. In the literature, energy management is portrayed as an integral aspect of comprehensive strategies. The concept of innovation is central, connecting energy efficiency with technologies like cross-cutting technologies and machine learning, which illustrate new applications of digital solutions to promote sustainability. Overall, exploring research areas such as driving forces, identifying barriers, and focusing on investments emphasizes the importance of frameworks and systematic support approaches to SME energy management. The principal concepts are illustrated in Figure 3.

3.3 Bibliographic Coupling

Using Bibliographic Coupling Analysis, this study aims to discover publications that are linked to each other by sharing common references in their bibliographies, to recognize clusters of publications performing on related subjects, and to classify rising research areas.

We have 14 documents as shown in Fig, 4. The first cluster focuses on organizational aspects of SMEs. The study by Gennitsaris et al. [2], the most recent in this network, extends previous research on organizational challenges and solutions, underscoring the contributions of SMEs to the climate targets of the Europe Union.

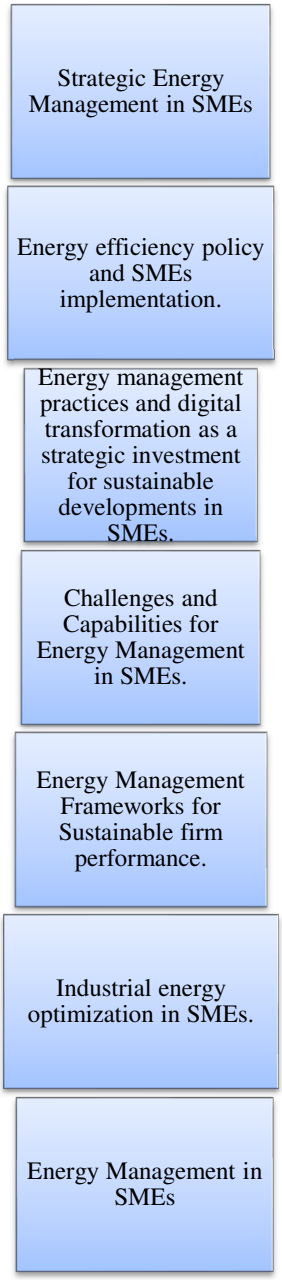

Fig 3. Principal concepts of Energy Management in SMEs field.

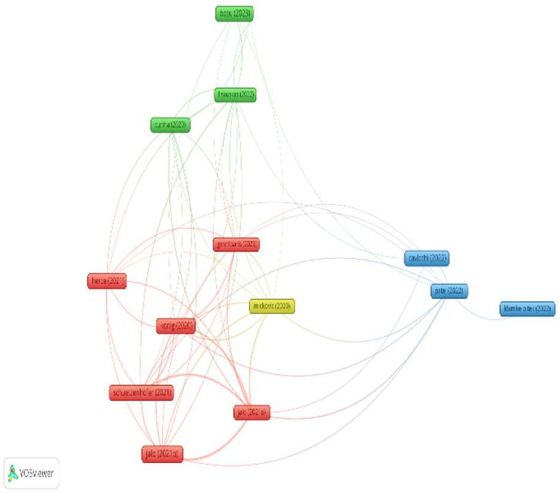

Fig. 4. Bibliographic coupling network visualization.

Herce et al. [13] present empirical evidence supporting the effectiveness of structured management approaches. The findings examine the relationship between ISO 50001 and energy audits in a specific case study within the context of the European Energy Efficiency Directive (EED), highlighting the importance of a structured energy management system to accompany audits. This cluster is anchored by the work of Jalo et al. [14] and Jalo et al. [15], who analyze the obstacles and motivations for energy management in manufacturing SMEs. According to Jalo et al. [14], organizational barriers and principal drivers are identified, and Jalo et al. [15] analyze the contribution of energy efficiency networks in overcoming them. The research of König et al. [16] adds an important human and cultural dimension to the analysis of how energy efficiency practices are established in SMEs. By analyzing the energy efficiency gap, Schützenhofer [17] provides empirical evidence that firms achieve greater savings potential with formal management system implementation.

This cluster highlights the applied aspects of conducting energy audits. In the case study presented by Bosu et al. [18], the authors develop a comprehensive energy audit and management plan for an industrial SME in Borg El-Arab City, Egypt. By estimating energy savings and CO2 emission reductions, the study shows best practices in energy audits and their outcomes. The adoption of Energy Efficiency Measures in Portuguese SMEs operating in non-residential buildings is examined by Cunha et al. [19]. The importance of absorptive capacity is noted, as the study found that more than 65% of respondents had never completed an energy audit, while over 8% did not employ an energy manager, indicating limited access to professional expertise. A study by Lalith and Kirubakaran [20] targets SMEs operating within the Siddha and Ayurveda medicinal field in India. Included in the study are energy audits, conservation evaluations, and the development of a grid-interactive rooftop solar photovoltaic power plant, complemented by economic and carbon emission reduction analyses. The case of Lithuanian SMEs represents another area where energy audits are applied. In their work, Lisauskas et al. [21] recommend energy efficiency strategies, along with projections of savings and reduced greenhouse gas emissions.

In Cluster 3, energy management is presented from a broader strategic and sustainability-oriented perspective. The study by Cavicchi et al. [22] underscores the importance of energy management and audits in supporting agricultural SMEs to achieve sustainability and circular economic outcomes. The research by Klemke and Majchrzak [23] assesses the influence of Polish SMEs' pro-environmental activities on competitive advantage and sustainable energy management, highlighting regional economic factors driving green behavior. The study by Patel et al. [24] links energy management practices in manufacturing firms to both environmental and financial outcomes, providing a robust theoretical and empirical foundation for organizational strategy.

Across the network, this cluster is represented solely by one paper, which is nonetheless highly connected. This research, conducted by Mickovic and Wouters [25], evaluates the availability and application of energy cost information in manufacturing, concluding that SMEs often lack essential cost information for effective energy management. Because of its strong bibliographic cooperation with the other clusters, the paper highlights energy cost data as a barrier to addressing organizational challenges.

4. CONCLUSIONS

Employing scientometric tools like co-occurrence and bibliographic coupling analysis on VOSviewer, the research makes notable contributions to academic knowledge and the practical implementation of SME energy management, highlighting its evolution across multiple structured research themes observed in the network. According to the analysis, six thematic clusters emerge: Strategic Energy Management in SMEs, Energy Efficiency Policy and SMEs Implementation, Challenges and Capabilities for Energy Management in SMEs, Energy Management Practices and Digital Transformation as a Strategic Investment for Sustainable Development in SMEs, Energy Management Frameworks for Sustainable Firm Performance and Industrial Energy Optimization in SMEs. The findings provide policymakers and SME managers with actionable insights into the barriers and drivers shaping successful implementation. In this context, the field progresses from strategic management to a more integrated approach, characterized by the adoption of sustainability goals reinforced by digital technologies and economic advantages. The clusters are interrelated, highlighting the connections established between barriers and absorptive capacity in determining successful implementation. The limitations of this research are linked to its design, reflecting only the past five years, dependence on the Web of Science database, and the restriction to English-language publications. Future work should concentrate on increasing the availability of energy cost data, evaluating the impact of absorptive capacity in overcoming implementation barriers within adapted SME frameworks, and promoting the integration of digital technologies for optimization and tangible outcomes.

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Managementul energetic în întreprinderile mici și mijlocii: analiza scientometrică a evoluției actuale a domeniului de cercetare

Întreprinderile mici și mijlocii (IMM-urile) sunt cruciale în promovarea obiectivelor de sustenabilitate. Această lucrare contribuie la înțelegerea managementului energiei în IMM-uri, luând în considerare impactul evoluțiilor contemporane. O analiză sistematică a 45 de articole din baza de date Web of Science cartografiază evoluția acestui domeniu în ultimii cinci ani. Din 2020, adaptarea post-pandemie, politicile climatice mai stricte, cum ar fi inițiativa dual de carbon a Chinei, și integrarea rapidă a inteligenței artificiale, a big data și a tehnologiilor inteligente au influențat agenda de cercetare. În consecință, urgența ca IMM-urile să adopte practici sustenabile s-a intensificat, definind această perioadă ca o etapă decisivă în executarea politicilor climatice și transformarea tehnologică. Constatările descriu metodele actuale de management al energiei și performanța sustenabilă în IMM-uri.

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