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Green Technology Adoption: A Systematic Review of Key Trends and Challenges

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ABSTRACT

This study systematically reviews the trends, drivers, and barriers of green technology adoption, synthesizing insights from 81 articles indexed in the Scopus database from 2019 to 2025. Employing the PRISMA framework and bibliometric analysis, the research aims to provide a comprehensive overview of the academic landscape and offer evidence-based guidance for stakeholders. The findings reveal a growing, albeit limited, academic interest, with a research peak in 2024. Geographically, the discourse is led by developed nations and emerging economies, notably China, while research predominantly focuses on high-impact sectors such as transportation, energy, and manufacturing, leaving critical sectors like agriculture under-examined. Furthermore, this review provides a theoretical contribution by mapping empirical findings onto the Green Innovation Cycle and the Stimulus-Organism-Response (S-O-R) model, thereby strengthening the explanatory power of existing frameworks. We identify key challenges spanning infrastructure, policy, and user behavior, and provide specific recommendations for policymakers, industry leaders, and researchers to foster a more equitable and effective green transition. This research serves as a robust scientific foundation for future studies and strategic initiatives to accelerate global green technology adoption.

I. INTRODUCTION

Green technology, or sustainable technology, encompasses eco-friendly innovations aimed at reducing pollution and conserving resources. It includes areas like renewable energy, waste management, and eco forestry [1]. The ecological advantages of green technology involve alleviating global warming through renewable energy sources and promoting sustainable agricultural and waste practices [2], [3]. Additionally, green technology supports social and economic sustainability by creating market opportunities and efficiencies, notwithstanding substantial initial costs [4], [5]. However, obstacles such as limited public awareness and the necessity for science-based policy frameworks continue to hinder effective implementation [6], [7].

Conducting a systematic literature review in green technology is essential for understanding research developments and challenges. The SLR highlights an increasing academic focus on green technology adoption from 2019 to 2024, with notable contributions from the European Union and prominent journals like the Journal of Cleaner Production. [8], [9]. A thorough comprehension of internal and external factors, such as management strategies, workforce involvement, and external partnerships, is essential, especially for SMEs [10], [11]. Moreover, consumer behavior and the mediating factors that influence green consumption are essential in shaping adoption patterns [12]. The recognition of various impediments underscores the need for focused innovation and mitigation strategies in sectors like automotive and environmental conservation [13]. The SLR constitutes a critical basis for evidence-informed policy, strategic management, and scholarly advancement that promotes sustainable green technology integration [14].

The literature review on green technology adoption offers numerous advantages. It integrates disparate studies, identifies knowledge deficiencies, and clarifies the dynamics of innovation in this field. This approach supports the development of theoretical models, including the cycle of green innovation and the Stimulus Organism Response (SOR) model, which guide subsequent research and applications [15]. Moreover, SLR encourages interdisciplinary collaboration among academia, industry, and policymakers. This collaboration facilitates the adoption of green technologies and sustainability transitions, ensuring environmental protection while advancing economic growth [16]. Ultimately, SLR not only enhances academic rigor but also provides practical insights for stakeholders to navigate adoption challenges and leverage emerging green opportunities.

This article systematically reviews 35 Scopus-indexed studies on green technology adoption. It analyses trends, motivators, and obstacles, providing evidence-based guidance for stakeholders. The results support strategic initiatives and collaborations to overcome adoption challenges and promote sustainable technology. Ultimately, this research establishes a solid scientific foundation for future studies and practical applications in global green technology implementation.

II. METHOD

The present research endeavors to examine the adoption of green technology by analyzing trends, motivating factors, and impediments through the application of a systematic literature review (SLR) and the PRISMA framework. A systematic literature review constitutes a rigorous methodology that systematically categorizes extant scholarly work and lays the groundwork for future investigations [17], [18].

A. Research Phases

The procedure initiates with the formulation of a specific research question and the development of a protocol designed to ensure transparency and methodological rigor [19]. A comprehensive literature review and screening process is undertaken utilizing stringent criteria to discern pertinent studies; nevertheless, this undertaking may be labor-intensive and susceptible to inaccuracies [20]. The stages encompass quality evaluation, data acquisition, and synthesis, frequently employing meta-evaluation methodologies to furnish a profound understanding of critical components that extend beyond mere frequency assessment [21], [22]. Ultimately, the results are disseminated in a methodical fashion, guided by checklists to maintain clarity and precision.

B. PICOC Framework and Research Questions

The first step was the PICOC framework shown in Table 1 to formulate specific research questions and to ensure a comprehensive and systematic review [23], [24]. The PICOC framework was chosen because of its contextual dimension, important for analyzing the adoption of green technologies in the technology domain. The framework provides a more holistic approach than PICO, which primarily focuses on interventions and outcomes and ignores the broader context of research.

TABEL I
PICOC FRAMEWORK

***PICOC* Component**	**Description**
Population	Smart factories applying IoT technology
Intervention	IoT-based smart systems for energy efficiency
Comparison	Conventional energy management methods
Outcome	Improved energy efficiency, reduced energy consumption, operational benefits
Context	Sustainable technology

The next phase, after establishing the PICOC framework, entails creating research questions (RQ) informed by this framework to guide the review process [25]. A SLR is guided by research questions that establish the research's parameters. Consequently, specific research questions were delineated.

RQ1. What are the main trends in green technology adoption in IT in recent years?

RQ2. Which regions lead research on green technology adoption, and what drives this?

RQ3. What are the key barriers to green technology adoption in IT based on research disciplines?

C. Data Sources and Screening Criteria

The selected database is Scopus, chosen based on a comprehensive assessment to optimize the literature search process. The search string used for literature retrieval is *green technology OR sustainable technology AND adoption OR acceptance OR uptake AND trend* OR driver* OR barrier* OR challenge**. Studies from the selected database are filtered based on titles, keywords, and abstracts.

Once the results have been acquired, the subsequent phase entails a meticulous screening process employing inclusion and exclusion criteria to delineate literature pertinent to the research objectives, encompassing aspects such as geographical location, source of publication, language, and date of publication [26], [27], [28]. The study's inclusion and exclusion criteria are outlined in Table 2. Title and Abstract Screening are employed to refine studies based on initial data. Subsequently, Full-Text Screening requires a comprehensive assessment of eligible studies, along with a Quality Assessment. Data extraction and management processes are facilitated by Zotero.

TABEL II
INCLUSION AND EXCLUSION CRITERIA

Topic	Inclusion	Exclusion
Database	Scopus	All other databases
Time frame	2019 - 2025	Article published before 2019 and after 2025
Document type	Article	All other document articles (e.g. Review, Conference paper, Book chapter and Book)
Language	English	Other languages
Publication stage	Final	Article in press
Keyword	Technology Adoption and Green Technology	Another keyword
Source type	Journal	Book, Conference proceedings and Book series
Open Access	All open access	Green, Gold, Hybrid gold and Bronze

D. PRISMA Model

The final step in the second stage is to comprehensively describe all processes in detail using the PRISMA methodology [29], [30] as illustrated in Figure 1. This methodology consists of three key phases: identification, screening, and inclusion.

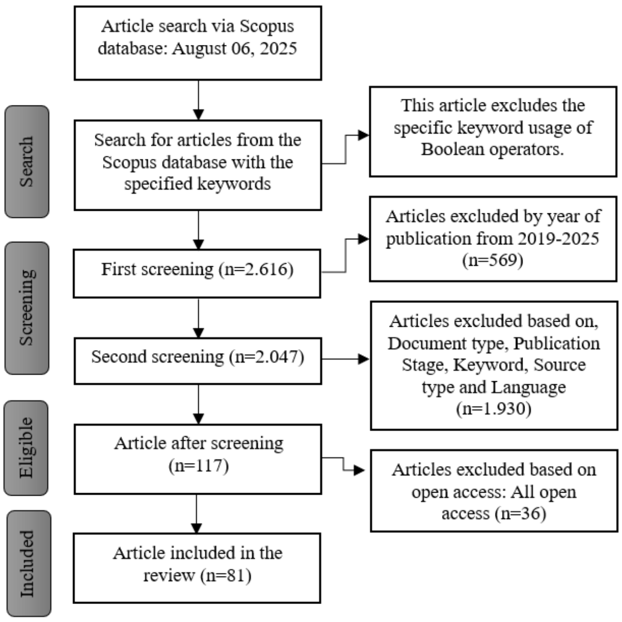

Figure 1. Systematic literature reviews information flow using PRISMA

Based on Figure 1, the initial stage entails keyword identification, retrieving 2.616 records. An initial screening follows, excluding studies by publication year, resulting in 2.047 records. A second screening phase refines the selection to 117 records. Ultimately, a full-text review is executed, producing 81 articles to validate the quality and credibility of the sources.

E. Thematic Analysis Technique

Following the PRISMA model, bibliometric analysis quantitatively underpins thematic analysis in systematic literature reviews, facilitating the identification of key research themes and knowledge structures via statistical mapping. This method advances the review process beyond mere data collection, allowing researchers to interpret and synthesize insights through the categorization of literature into significant thematic clusters, thereby improving analytical rigor and depth while reducing biases typical of qualitative synthesis [31].

III. RESULT AND DISCUSSION

This research examines four research questions based on findings from 81 articles in the Scopus database regarding green technology adoption: trends, drivers, and barriers. The data is sourced from published article counts, annual publication trends, and journal origins. Furthermore, the study will elucidate the key factors influencing green technology adoption, such as authors, affiliations, participating countries, and the overall impact of green technology adoption.

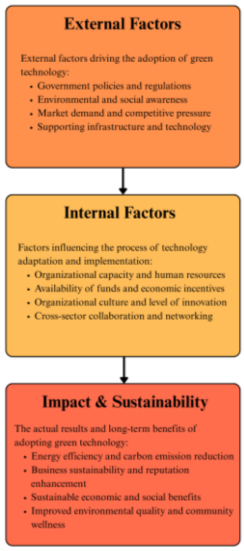

Figure 2. Green technology adoption framework

This discussion section discusses the complexities of green technology adoption, highlighting its significance for global sustainability. It presents a conceptual framework, as shown in Figure 2, which categorizing factors into External (government policies, environmental awareness, market demand, infrastructure), Internal (organizational capacity, funding, culture, collaboration), and Impact & Sustainability (energy efficiency, business continuity, economic and social benefits, environmental quality improvement). By synthesizing these elements, the framework offers a thorough understanding of barriers and drivers, providing insights for policymakers, investors, and organizations focused on sustainable technology adoption.

A. Green Technology Adoption Trends

According to Scopus data, scholarly work on green technology adoption: trends, drivers, and barriers includes 81 articles over five years, indicating limited investigations in this area, as shown in Figure 3.

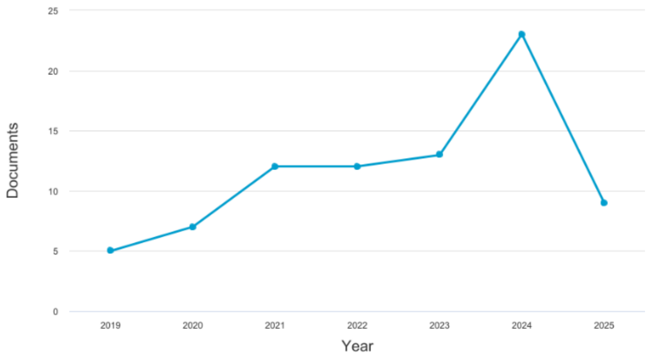

Figure 3. Trend of green technology adoption publication

Figure 3 shows the trend in research publications on the adoption of green technology from 2019 to 2025. There was a gradual increase in the number of documents from 2019 to 2021, followed by relatively stable publication numbers in 2022 and 2023, before reaching a high point in 2024. However, in 2025, there is a significant decline in the number of publications. This pattern indicates an increase in research interest in green technology over the past few years, with a peak in attention in 2024, followed by a decline in 2025 due to several factors, including the research cycle or data limitations until mid-2025.

B. Distribution of Studies on Green Technology Adoption

The distribution analysis of green technology adoption research was conducted by categorizing 81 articles by country classification, focusing on the top 10 articles in each category as shown in Figure 4. Insights into the distribution of research funding related to green technology will benefit scholars and practitioners in shaping future research directions, particularly in the context of sustainable development in green technology adoption.

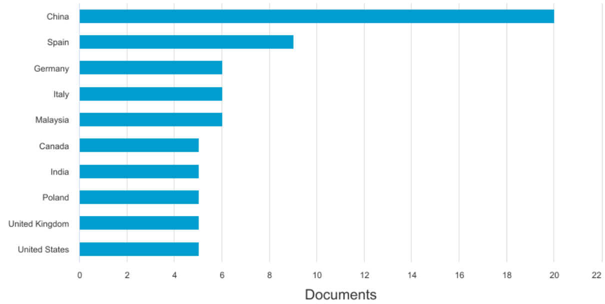

Figure 4. Number of articles by top 10 country

Figure 4 illustrates the distribution of research articles on green technology adoption across the ten leading contributing countries. China leads with 20 publications, followed by Spain with 9. Other developed nations, including Germany, Italy, Canada, Poland, and the United Kingdom, contribute significantly with 5 to 6 articles each. Additionally, developing nations like Malaysia and India are also noteworthy, with 6 and 5 articles, respectively. This graph demonstrates the predominance of developed nations in green technology research and the increasing participation of developing countries.

The network visualization depicts global connectivity and diverse scientific contributions in green technology research, as shown in Figure 5. Major research centers, including China, the United Kingdom, and the United States, serve as central nodes, highlighting their crucial influence in this field. This representation demonstrates the importance of global collaboration in driving research progress and knowledge exchange in this rapidly evolving sector.

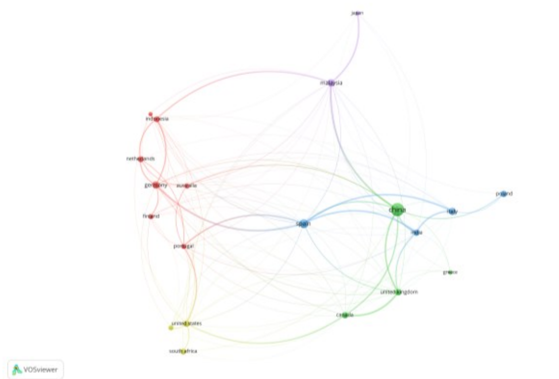
Figure 5. Network country visualization

Figure 5 depicts the international collaboration network in green technology research across diverse countries. The visualization reveals strong connections between developing and developed nations across multiple continents. This signifies a robust global collaboration that enhances knowledge and resource exchange in green technology research. Consequently, sustainability and innovation in environmentally friendly technology arise from diverse collaborations, highlighting that global environmental issues necessitate cross-regional partnerships beyond developed nations.

C. Disciplinary Distribution of Research in Green Technology Adoption

The analysis categorized 81 articles on green technology adoption by subject area, highlighting key categories in Figure 6. This visualization is essential for identifying the disciplinary perspectives most frequently addressing barriers to green technology adoption, thereby directly answering our third research question regarding key barriers based on research disciplines.

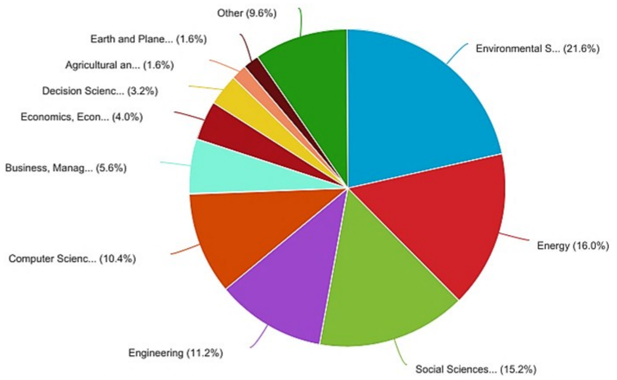

Figure 6. Subject area of green technology adoption

Figure 6 depicts the research landscape on green technology adoption based on 35 Scopus articles. Environmental Science (21.6%) and Energy (16.0%) dominate, reflecting a focus on ecological and resource efficiency. Social Sciences (15.2%), Engineering (11.2%), and Computer Science (10.4%) contribute to diverse perspectives to the field. This multidisciplinary nature emphasizes the complexity of barriers to green technology adoption across various domains. Technical issues related to performance are examined in engineering and computer science, while economic challenges are discussed from a business perspective. Social resistance is analyzed within social sciences, and environmental policies are studied in environmental science.

To complement the disciplinary distribution analysis, Figure 7 illustrates a co-occurrence framework of key terms in green technology adoption research. This visualization emphasizes the interconnections between concepts such as "technology adoption," "sustainability," and "green technology," along with sub-themes like environmental protection, carbon emission, and renewable energy. It underscores the multidisciplinary and interconnected essence of this research domain, elucidating thematic clusters that attract scholarly focus.

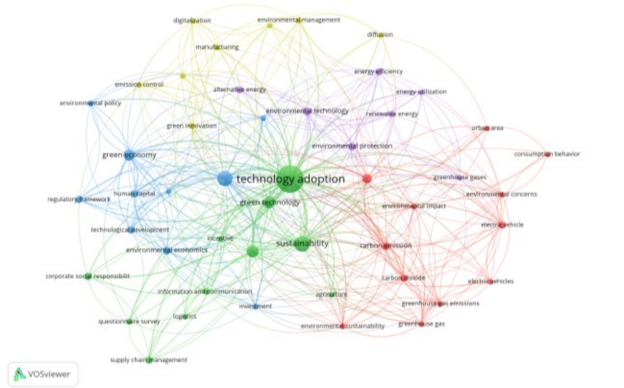

Figure 7. Key Terms Co-occurrence in Green Technology Adoption

TABEL III
TOP 10 KEYWORDS BY OCCURRENCES AND LINK STRENGTH IN GREEN TECHNOLOGY ADOPTION RESEARCH

Rank	Keyword	Total Link Strength
1	Technology adoption	298
2	Innovation	134
3	Sustainability	114
4	Sustainable development	68
5	Green economy	67
6	Climate change	55
7	Green technology	45
8	Carbon emission	44
9	Environmental technology	43
10	Carbon dioxide	37

Figure 7 and Table III present an overview of key themes in green technology adoption research. The co-occurrence network illustrates the interconnections among various concepts, highlighting clusters on innovation and sustainability. The top 10 keywords in the table emphasize the significance and complexity of these academic areas.

D. Sectoral Analysis of Green Technology Adoption

The adoption of green technology varies significantly across sectors. A sectoral analysis is essential for a nuanced understanding of the research landscape. This approach provides essential insights for policymakers and industry leaders in designing targeted interventions. By identifying leading and lagging sectors, the study aims to offer evidence-based guidance that is theoretically sound and practically relevant.

A systematic review indicates predominant research in transportation, energy, and manufacturing. This emphasis arises from the substantial carbon emissions and their vital contribution to global sustainability. The transportation sector has undergone extensive research on electric vehicles and alternative fuels, encompassing infrastructure, policy, and consumer behavior. Likewise, the energy and manufacturing sectors are pivotal in advancements in green technology, focusing on renewable energy, the circular economy, and sustainable supply chains. This research concentration reflects a global consensus on the necessity to decarbonize these critical industries.

Research shows that agriculture and fisheries are inadequately studied. The lack of publications reveals substantial research deficiencies and slow adoption of green technologies. These deficiencies stem from specific challenges, including high costs of custom technologies, insufficient technological expertise among practitioners, and the lack of focused policy frameworks. Consequently, the constraints of academic dialogue impede the development of customized solutions, leaving these vital economic sectors lagging in the shift towards sustainability.

E. Green Technology and Infrastructure

Green technology adoption encounters significant challenges, including infrastructure, technology, investment, and support [32]. The electric vehicle sector is impeded by inadequate charging station distribution, affecting user confidence. Moreover, emerging technologies like solar paving encounter maintenance and financial sustainability issues that hinder scalability [33]. Technological and organizational preparedness also significantly affect adoption rates. Resistance toward new technologies like blockchain in aquaculture is largely due to unfamiliarity and perceived complexity, slowing integration into existing workflows [34].

High initial costs are a significant obstacle. Alternative fuel vehicles entail considerable financial investment for acquisition and fleet modifications. Likewise, elevated maintenance expenses of solar paves deter prospective investors. Adequate facilities are crucial for green technology. A unified and accessible charging infrastructure is vital for electric vehicles. In healthcare, innovations rely on institutional support like education and training programs [35].

Enhancing green technology adoption requires a multifaceted strategy involving infrastructure, technological readiness, financial systems, and support facilities. These integrated strategies are essential for promoting sustainable growth and maximizing the environmental advantages of green technologies.

F. Supporting Policies and Regulations

The interplay among policy constraints, regulatory ambiguities, and financial incentives is crucial for the promotion of innovation and adoption in green technologies. Principal obstacles encompass the absence of well-defined policies for nascent technologies such as Hydrothermal Carbonization (HTC) and the inadequacy of regulations within circular economic frameworks, which impede effective implementation and collaborative efforts [36]. Regulatory uncertainty also affects investment decisions, as unpredictable environmental regulations can deter firms despite their potential long-term benefits when well-designed [37].

Fiscal policies, encompassing subsidies and tax credits, play a pivotal role in diminishing the costs associated with innovation and motivating sustainable investments. Nonetheless, it is imperative to exercise caution to prevent the displacement of private investment, thereby ensuring that incentives foster market sustainability [38]. In conclusion, it is vital to address regulatory deficiencies and uncertainties while deliberately implementing fiscal incentives to cultivate a conducive environment for the advancement of green technologies.

G. Economic and Financial Aspects

The economic and financial dimensions are essential for the integration of sustainable technologies across sectors, particularly in supply chain finance and green innovation pursuits. Financing alternatives like peer-to-peer (P2P) lending platforms facilitate direct connections between capital-constrained manufacturers and investors, impacting pricing dynamics in sensitive markets. Government interventions, including policies and incentives, are crucial for promoting green technology adoption in small and medium enterprises [39].

Investment risks pose notable challenges in electric vehicle (EV) and alternative fuel vehicle (AFV) sectors. High initial capital requirements and liquidity concerns deter potential investors. Market volatility and evolving consumer preferences further complicate the profitability and viability of new technologies. Budgeting must account for total cost of ownership (TCO), including infrastructure and operational costs for effective technology deployment. Leasing is frequently utilized to alleviate initial financial burdens, facilitating the adoption of sustainable technologies [40].

The high perceived costs of electric vehicles hinder their adoption. Strategic policies and incentives are essential to mitigate these cost concerns and enhance acceptance. Additionally, financing and leasing options reduce financial risks, promoting wider adoption [41]. In summary, diversified financing strategies, investment risk management, comprehensive budgeting with TCO, and cost mitigation policies are essential for sustainable technology adoption. These financial elements enhance organizational innovation and sustainability. Future research ought to explore the long-term impacts of these financial strategies on sustainable development.

H. Social Awareness and User Behavior

The adoption of innovative technologies, particularly in renewable energy, hinges on awareness, education, organizational culture, and user resistance. Awareness enhances understanding and support for new technologies. Public knowledge of renewable energy, exemplified by electric vehicle adoption, cultivates favorable attitudes essential for acceptance. Campaigns and educational programs effectively drive behavioral change and mitigate resistance by highlighting environmental benefits and technological attributes [42], [43].

Education significantly boosts user confidence and comprehension of environmental advantages, facilitating adoption by minimizing resistance [42]. Organizational culture that supports sustainability and innovation fosters acceptance and employee engagement [44]. User resistance, stemming from habits or complexity, can be alleviated by clear communication, education, and fostering an innovative environment [45]. Enhancing these elements is crucial for effective adoption of green technology.

I. Research and Innovation in Digital Technologies for Green Tech

The incorporation of digital technology across various domains fosters notable innovations yet encounters specific obstacles. Principal challenges in innovation encompass technological constraints, including infrastructure deficiencies in education that impede tailored digital learning intended to promote computational thinking. Organizational resistance and technological complexity hinder implementation [33].

Digital technology facilitates personalized learning, improving engagement and skill acquisition [45]. Nonetheless, successful integration necessitates strong infrastructure and support. Inadequate technological infrastructure hinders the efficacy of digital learning in education. In conclusion, digital technologies possess significant potential for innovation in green technology, but it is essential to overcome various barriers. Future research must aim to create strategies to tackle these obstacles and promote sustainable innovation.

J. Theoretical Implications and Framework Mapping

The systematic review elucidates trends and barriers while reinforcing theoretical frameworks like the Green Innovation Cycle and S-O-R model. Barriers to green technology adoption, including poor infrastructure, significant upfront costs, and regulatory uncertainties, align well with the Green Innovation Cycle [46]. These factors significantly hinder the advancement of green technologies from development to market integration. Specifically, ambiguous policies and considerable financial barriers extend this cycle, thus delaying the transition to a sustainable economy [47].

Furthermore, the S-O-R model elucidates the analysis of social awareness and user behavior regarding digital green innovations. Within this paradigm, external influences such as educational initiatives, positive market indicators, and conducive policies serve as the Stimulus [48]. These stimuli affect the cognitive processes of entities the Organism modulating their knowledge, awareness, and attitudes regarding green technology. This influences their adoption behaviors, reflecting the Response. The resistance to new technologies is interpreted as a subdued reaction due to inadequate stimulation, including insufficient education or communication, which undermines user confidence and familiarity [49].

This study enhances understanding of green technology adoption mechanisms. The Green Innovation Cycle outlines the development path and its challenges, while the S-O-R model clarifies the behavioral factors influencing adoption. This combined theoretical approach enhances academic rigor and establishes a solid basis for future research and interventions [50].

K. Practical Implications and Recommendations for Stakeholders

This study presents valuable insights from a comprehensive analysis of green technology adoption literature, serving as a vital resource for stakeholders addressing contemporary issues. Our findings culminate in a series of evidence-based recommendations specifically designed for policymakers, industry leaders, and the academic sector.

For policymakers, our research highlights the necessity for specialized interventions. The notable research gap in our sectoral analysis emphasizes the need for tailored regulatory frameworks and financial incentives for underperforming sectors, particularly agriculture and aquaculture. While support for leading sectors like transportation is important, an equitable approach addressing the specific challenges of less-studied areas is critical. Furthermore, to enhance Stimulus within the S-O-R model, policymakers should emphasize transparent, long-term regulatory certainty to strengthen investor and consumer trust.

For industry leaders, our study indicates that overcoming adoption barriers necessitates a comprehensive strategy integrating financial innovation and internal capacity enhancement. Companies should explore financing alternatives like leasing and P2P lending to alleviate initial costs. To counter user resistance, leaders ought to invest in training and educational initiatives to improve technological familiarity and foster a sustainability-oriented organizational culture. These initiatives directly respond to market stimuli, promoting internal and external green innovation. Lastly, for academics and researchers, our work underscores a notable research deficiency regarding the long-term effects of financial strategies and policy measures. Future research should emphasize longitudinal analyses and aim to devise customized solutions for less-explored sectors to facilitate a more equitable green transition.

IV. CONCLUSION

This systematic literature review addresses a significant knowledge gap regarding green technology adoption by synthesizing insights from 81 Scopus-indexed articles. Utilizing a PRISMA-guided methodology and bibliometric, our study offers a thorough overview of the current discourse on green technology. The research delineates the academic landscape, revealing an increasing interest that peaked in 2024, emphasizing the roles of developed nations and emerging economies such as China, while also highlighting interdisciplinary perspectives from environmental science, energy, and social sciences. Our results culminate in a robust conceptual framework that incorporates internal, external, and impact factors, providing a structured approach to understanding the complexities of sustainable technology integration.

A significant contribution of this study is its detailed insight through a refined sectoral and theoretical examination. The research predominantly centers on high-impact sectors, leaving vital areas like agriculture and aquaculture notably under-explored. Additionally, this review makes an important theoretical contribution by correlating the identified barriers and drivers with the Green Innovation Cycle and the Stimulus-Organism-Response (S-O-R) model. By illustrating how elements such as policy uncertainty and elevated costs hinder the innovation cycle, and how social awareness and educational initiatives act as incentives for adoption, we have reinforced the theoretical basis for future investigations into green technology adoption behavior.

This study has limitations due to its reliance on a single database and a specific time frame. Future research should broaden its focus to encompass additional databases and longer time periods. Longitudinal analyses are recommended to assess the enduring impact of various strategies on the adoption cycle. This research establishes a robust foundation for stakeholders to develop evidence-based strategies for a just green transition. By encouraging collaboration and innovation, we can utilize green technology for a sustainable future.

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