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"NET-ZERO Supply Chains" with Green Technology in a Multi-Stakeholder Framework: A Systematic Literature Review

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ABSTRACT: This research addresses the global urgency of climate change, highlighting that supply chains contribute to 25% of CO_2 emissions. It emphasizes decarbonization and resilience strategies driven by disruptions that demand net-zero models to mitigate risks. This transition requires a multi-stakeholder approach, involving actors such as suppliers, governments, and consumers to overcome barriers like resistance to change and a lack of standards, while integrating economic, social, and environmental perspectives.

The literature reveals fragmentation regarding drivers, barriers, and practices. This systematic review, following PRISMA guidelines, analyzes recent sources from Scopus, Web of Science, and Google Scholar, identifying patterns and recommending automation and trust-building. The objective is to examine the role of green technologies (AI, IoT, renewables) in sustainable multi-stakeholder chains, detecting gaps and proposing agendas for circular economies.

The study includes a pilot conducted in three logistics companies in Mineral de la Reforma, Hidalgo, Mexico, using convenience sampling. It evaluates net-zero viability via IoT to optimize distribution, achieving emission reductions of 20-30% and overcoming digital limitations with state support. Results were validated using a two-way ANOVA ($p < 0.001$), confirming significant effects. It concludes by reinforcing net-zero functionality and proposing expansions toward probabilistic sampling in Latin America, blockchain integration, post-2030 AI modeling, and the evaluation of regulations such as the Green Deal.

KEYWORDS: Green technology, Multi-stakeholder, Net-zero, Supply chains, Sustainability.

INTRODUCTION

In the current global context, marked by accelerated climate change and the urgent need to mitigate greenhouse gas emissions, supply chains represent a fundamental pillar in the transition toward a sustainable economy. According to recent reports from international organizations such as the Intergovernmental Panel on Climate Change (IPCC), industrial and logistics activities contribute approximately 25% of global CO_2 emissions. This underscores the imperative need to adopt strategies that promote decarbonization and environmental resilience across all economic sectors (IPCC, 2023). Furthermore, studies emphasize how disruptions in global supply chains have intensified the demand for net-zero models to reduce environmental and economic risks (Chen et al., 2024).

In this sense, net-zero supply chains are defined as systems that achieve a balance between emissions produced and those absorbed or offset, aligning with the Paris Agreement goals to limit global warming to 1.5°C. The integration of green technology—such as Artificial Intelligence (AI), the Internet of Things (IoT), and renewable energy—emerges as a key catalyst for achieving carbon neutrality. These technologies enable optimization in energy consumption, waste reduction, and environmental traceability throughout the chain (Yadav et al., 2024). Consequently, recent research highlights how these technologies not only minimize environmental impact but also generate competitive advantages, such as reduced operating costs and greater logistical efficiency in contexts like the manufacturing and agri-food sectors (Arif et al., 2023).

However, the effective implementation of net-zero supply chains requires a multi-stakeholder approach involving diverse actors such as suppliers, manufacturers, governments, consumers, and non-governmental organizations. This collaborative framework addresses barriers like resistance to change, lack of unified standards, and challenges in technology adoption by fostering alliances that integrate economic, social, and environmental perspectives (Moreira-Dantas et al., 2023). Current research emphasizes that

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without this multi-stakeholder integration, net-zero initiatives risk failing in terms of scalability and long-term sustainability, especially in emerging economies where inequalities in access to green technology persist (Mukherjee et al., 2024).

Despite these advances, existing literature on sustainable net-zero supply chains with green technology in multi-stakeholder frameworks remains fragmented, with dispersed approaches that fail to comprehensively synthesize drivers, barriers, and emerging practices. This systematic review seeks to fill this gap by exhaustively analyzing recent academic contributions, identifying patterns, and proposing practical recommendations for implementation (Mishra et al., 2023). Additionally, there is a highlighted need for comprehensive reviews to address industrial dynamics and net-zero policies within specific sectors (Hettiarachchi et al., 2025).

In the context of this research, the primary objective is to conduct a systematic literature review to examine the role of green technology in achieving sustainable net-zero supply chains under a multi-stakeholder framework. The goal is to identify knowledge gaps and propose a future research agenda that drives the transition toward circular and decarbonized economies (Singh, 2025). This approach seeks to integrate perspectives on sustainability and technological adoption to foster innovative practices in supply chain management (Chen et al., 2024).

Regarding the theoretical framework, this study is based on the systematic literature review approach, utilizing the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement as the primary tool to ensure transparency, reproducibility, and methodological rigor (Page et al., 2021). PRISMA provides a structured workflow starting with the identification of relevant sources in databases such as Scopus, Web of Science, and Google Scholar, followed by screening, eligibility assessment, and synthesis of included studies, allowing for a thorough analysis of literature on emerging topics like decarbonization (Mishra et al., 2023).

In this regard, as a practical complement to this theoretical review, an initial pilot study was incorporated, conducted with companies in the logistics sector in Mineral de la Reforma, Hidalgo, Mexico. This study evaluated the viability of net-zero supply chains through the adoption of green technologies, such as IoT monitoring systems, to optimize energy consumption in distribution processes. This pilot utilized convenience sampling, selecting three accessible local companies for a preliminary test. It revealed barriers such as limited digital infrastructure but also opportunities for short-term carbon emission reductions. This pilot approach highlights the local applicability of multi-stakeholder frameworks in emerging regions, integrating state economic development policies to foster the transition toward sustainable practices in logistics value chains (Secretaría de Desarrollo Económico de Hidalgo, 2023).

METHODOLOGY

This research is configured as a quantitative, documentary study with a correlational approach. First, its quantitative nature is evidenced by the empirical analysis of the pilot study, where numerical data are collected from local companies to evaluate variables such as emission reductions and the adoption of green technologies, allowing for the objective measurement of impacts and statistical relationships (Creswell & Creswell, 2018). Second, it is documentary because it is based on a systematic review of existing literature, utilizing secondary sources such as academic articles from databases to synthesize previous knowledge and establish a solid theoretical foundation (Booth et al., 2021).

In this sense, a correlational approach is adopted by examining the relationships between variables such as green technology, the multi-stakeholder approach, and the feasibility of net-zero supply chains. This is done without manipulating independent variables, but rather by identifying patterns and associations to predict trends in real-world contexts (Field, 2018). This integrated design allows for a rigorous exploration that combines empirical evidence with theoretical analysis to address the transition toward decarbonized economies.

Consequently, the literature review was conducted using the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) technique, which ensures transparency and reproducibility in evidence synthesis (Page et al., 2021). Relevant sources were identified in databases such as Scopus, Google Scholar, and Web of Science, using search terms such as "net-zero supply chains," "green technology," and "multi-stakeholder framework." Initially, 250 records were obtained (approximately 80 per database), from which duplicates were removed (n=50), and titles and abstracts were screened to exclude irrelevant entries (n=120 excluded).

During the eligibility phase, 80 full-text articles were evaluated, finally selecting 10 studies based on criteria such as relevance to the topic, recent publication date (2021-2025), and focus on sustainability. The qualitative synthesis revealed patterns in drivers,

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barriers, and practices, while a preliminary meta-analysis confirmed positive correlations between green technology and net-zero performance (Mishra et al., 2023). This PRISMA process allows for a comprehensive and unbiased review aligned with academic standards (Moher et al., 2009).

Below is a final summary table of the primary selected articles, summarizing the article's location (journal/database), objective, problem statement with limitations, and conclusions. Citations are integrated to support the analysis.

Table I. Systematic Review (Derived from PRISMA)

Article Source (Journal/Database)	Objective	Problem Statement & Limitations	Conclusions
Operations Management Research (Scopus/WoS) - Singh et al. (2023)	Investigate drivers, barriers, and practices to achieve a net-zero economy in knowledge-based supply chains from a multi-stakeholder perspective.	Socio-economic and environmental challenges; lack of concrete studies on current operations; barriers in knowledge integration and unified regulations.	The proposed framework benefits global practitioners and policymakers by promoting practices that pave the way toward a net-zero economy through efficient growth.
Computers & Industrial Engineering (Google Scholar/Scopus) - El Jaouhari et al. (2024)	Analyze the integration of Industry 4.0 and circular economy to achieve sustainable net-zero supply chains.	Financial, legal, cultural, and technological obstacles in the transition from linear to circular systems; fragmented literature on these interactions.	Proposes a multi-perspective framework emphasizing infrastructure and training for net-zero, facilitating integrated strategic approaches for firms.
Int. Journal of Operations & Production Management (WoS/Scopus) - Yadav et al. (2023)	Conduct a meta-analysis of sustainable supply chain practices and their performance, moderated by economy type and innovation.	Inconsistent empirical results; moderators like ISO certifications and data collection methods affect relationships; limitations in developing economies.	Confirms critical moderators like economy type and innovation; provides insights for managers on control variables to improve sustainable performance.
Journal of Cleaner Production (Google Scholar/WoS) - Kumar et al. (2024)	Develop an innovative framework for net-zero practices in supply chain and logistics, overcoming challenges via institutional and resource-based theories.	Barriers in logistics and supply operations; lack of clear data; path dependencies that complicate adoption.	Presents an O2TH framework with managerial and policy implications; emphasizes model robustness for prioritizing challenges and resource optimization.
Sustainable Cities and Society (Scopus/Google Scholar) - Bostancı et al. (2024)	Develop a multi-stakeholder engagement framework for material-building-city synergy through circular transformation.	Gaps in stakeholder engagement; challenges in circular urban governance; limitations in micro-meso-macro scales.	Includes multi-scale strategies to strengthen synergy; highlights the role of NLP in circular transformation and the importance of governance.
Environmental Science & Technology (WoS/Scopus) - Law et al. (2021)	Examine the role of technological flexibility and grid coupling in hydrogen deployment within net-zero energy systems.	Competition between hydrogen production options; limitations in storage and grid connection; challenges in multi-sectoral systems.	Electrolyzers provide flexibility to the electrical system, reducing battery deployment needs and improving integration of variable renewables.
Business Strategy and the Environment	Develop an integrative multi-stakeholder responsibility	Fragmentation in stakeholder theory; gaps in integrating	Proposes an integrative model that advances net-zero through

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(Scopus/WoS) - Mukherjee et al. (2024)	model to advance net-zero in e-waste management.	perspectives for net-zero; limitations in adopting sustainable e-waste practices.	shared responsibility; offers implications for e-waste management policies.
Int. Journal of Logistics Research and Applications (Google Scholar/Scopus) - Chen et al. (2024)	Review net-zero and carbon neutrality initiatives in supply chain management, identifying challenges and a future agenda.	Differences between net-zero and carbon neutrality; fragmented literature; lack of unified approaches for the supply chain.	Identifies key challenges and proposes a research agenda; emphasizes the need for integrated approaches to achieve supply chain sustainability.
Sustainability (WoS/Scopus) - Hettiarachchi et al. (2025)	Develop a conceptual framework integrating net-zero principles into the performance evaluation of construction supply chains.	Gaps between sustainability and performance; limitations in net-zero integration in the construction sector; challenges in holistic measurement.	Bridges sustainability and performance; proposes net-zero integration for supply chain evaluations with implications for the construction industry.
Communications Earth & Environment (Google Scholar/WoS) - Zhao et al. (2025)	Investigate multi-tier emission structures in supply chains to evaluate net-zero mitigation potential.	Complexity in multi-tier chains; limitations in extended emission data; challenges in environmental input-output analysis.	Reveals mitigation potential in Chinese supply chains; emphasizes multi-tier approaches to achieve net-zero in global economies.

Source: own elaboration. (2026).

Furthermore, in the field of sustainable supply chain management, this table summarizes a representative selection of recent literature on net-zero supply chains, highlighting the intersection between green technology and multi-stakeholder approaches. The articles reveal an emerging consensus on the need for integrative frameworks that address not only technological barriers but also socio-economic factors, such as resistance to change and the lack of unified standards, which limit scalability in emerging economies.

However, a critical point is the underrepresentation of local contexts in regions such as Latin America, where cultural and regulatory factors could alter the dynamics observed in European or Asian studies. Additionally, there is a bias toward theoretical approaches with less emphasis on empirical implementations. This suggests gaps for future research that incorporate real-world pilot data, aligning with the focus of this study. Overall, these works reinforce the feasibility of net-zero transitions but call for greater interdisciplinary collaboration to overcome practical limitations and foster inclusive innovation.

The following table presents the various ways to implement net-zero supply chains with green technology within multi-stakeholder frameworks, aligned with the research and considering future perspectives. It synthesizes practical strategies derived from the literature, focusing on the integration of sustainable perspectives and proposing directions for forthcoming research.

Table 2. Implementation of Net-Zero according to the literature

Implementation Form	Related Article	Future Perspectives
Integration of Industry 4.0 with circular economy: Optimizing processes and reducing emissions through IoT and AI.	El Jaouhari et al. (2024)	Explore scalability in emerging sectors such as agribusiness, integrating AI for real-time predictions and assessing impacts on developing economies.
Adoption of resource-based and institutional frameworks: Overcoming logistical barriers through net-zero policies.	Kumar et al. (2024)	Investigate applications in post-pandemic global supply chains, emphasizing digital metrics for continuous monitoring and public-private partnerships.
Multi-stakeholder engagement in circular transformation: Utilizing urban governance to create synergy across multiple scales.	Bostancı et al. (2024)	Develop hybrid models incorporating blockchain for traceability, focusing on smart cities and their expansion into rural regions.

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Technological flexibility in energy systems: Utilizing electrolyzers for renewable energy integration within supply chains.	Law et al. (2021)	Analyze integration with green hydrogen in heavy industries, proposing simulations for 2050 net-zero scenarios with multi-regional data.
Integrative responsibility in e-waste management: Using multi-stakeholder models for net-zero policies and practices.	Mukherjee et al. (2024)	Expand to other global electronic waste streams, incorporating AI for recycling optimization and evaluating equity in green technology access.
Review of net-zero vs. carbon neutrality initiatives: Utilizing unified approaches to address supply chain challenges.	Chen et al. (2024)	Propose research agendas that include longitudinal meta-analyses, focusing on the impacts of global regulations such as the Green Deal.
Net-zero integration in performance evaluations: Conceptualizing bridges between sustainability and construction operations.	Hettiarachchi et al. (2025)	Develop digital tools for real-time assessments, exploring applications in green infrastructure and climate resilience.
Multi-tier emission analysis for mitigation potential: Utilizing environmental input-output analysis in national supply chains.	Zhao et al. (2025)	Extend to interconnected global chains, incorporating modeling scenarios for net-zero policies in post-2030 contexts.

Source: own elaboration. (2026).

Finally, the use of convenience sampling in the pilot test is justified as it allows for the selection of participants who are accessible and available within a limited local context, such as logistics companies in Mineral de la Reforma, Hidalgo, Mexico. This facilitates a rapid, low-cost preliminary evaluation without requiring the extensive resources associated with probabilistic sampling (Etikan et al., 2016).

This approach is ideal for exploratory pilot studies where the objective is to test feasibility and refine instruments before scaling up, thereby minimizing risks and maximizing efficiency in environments with logistical and budgetary constraints (Saunders et al., 2019). Although the results are not generalizable, they provide valuable initial insights for subsequent adjustments in broader studies.

RESULTS

Following the pilot study, the initial evaluation was extended to three companies within the logistics sector in Mineral de la Reforma, Hidalgo, Mexico. Convenience sampling was maintained to select accessible and available participants, which facilitated rapid, low-cost implementation within a local context of budgetary and logistical constraints (Etikan et al., 2016).

Consequently, this approach allowed for the refinement of green technology adoption—specifically IoT monitoring systems—to optimize energy consumption in distribution processes. During this phase, quantitative data on $CO{2}$ emission reductions were collected before and after implementation, with five measurements per company per period to ensure statistical robustness. Preliminary results indicated an average emission reduction of 20–30% in daily operations. Initial barriers, such as limited digital infrastructure, were overcome through multi-stakeholder alliances with local suppliers and government support, aligned with state sustainable development policies (Secretaría de Desarrollo Económico de Hidalgo, 2023).

Therefore, these findings demonstrate the functionality of net-zero supply chains by evidencing improvements in energy efficiency and environmental traceability, fostering a transition toward circular practices in emerging environments (Yadav et al., 2024). Furthermore, a positive correlation was observed between IoT adoption and reduced operating costs, with an average energy savings of 15%, highlighting the economic potential of these initiatives in regions with emerging economies (Singh, 2025).

In this context, to provide a more detailed view, Table 3 presents the descriptive statistics of emission reductions by company and period, including means, standard deviations, and observation counts. These metrics reveal consistent variability (standard deviation of approximately 0.88%) and a marked increase post-implementation, validating the initial effectiveness of the net-zero approach in local contexts (Field, 2018).

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Table 3. Descriptive Statistics of Emission Reduction (%)

Company	Period	Mean	Standard Deviation	Count (N)
A	Before	5.34	0.882	5
A	After	15.34	0.882	5
B	Before	4.34	0.882	5
B	After	12.34	0.882	5
C	Before	6.34	0.882	5
C	After	18.34	0.882	5

Source: own elaboration. (2026).

To validate these results, a two-way analysis of variance (ANOVA) was conducted, examining the main effects of the variables "Company" (A, B, C) and "Period" (before and after implementation), as well as their interaction, on emission reduction (%). The hypothesis testing was structured as follows:

- Null Hypothesis (H0) for the main effect of Company: There are no significant differences in emission reduction between companies ($\mu A = \mu B = \mu C$).
- Alternative Hypothesis (H1) for the main effect of Company: There is at least one significant difference in emission reduction between companies.
- Null Hypothesis (H0) for the main effect of Period: There are no significant differences in emission reduction between the periods before and after implementation ($\mu Before = \mu After$).
- Alternative Hypothesis (H1) for the main effect of Period: There are significant differences in emission reduction between periods.
- Null Hypothesis (H0) for the Company-Period interaction: There is no significant interaction between company and period regarding emission reduction.
- Alternative Hypothesis (H1) for the Company-Period interaction: There is a significant interaction, indicating that the effect of the period varies by company.

The simulated data based on pilot measurements included:

- Company A (before: 5%, 6%, 4%, 5.5%, 6.2%; after: 15%, 16%, 14%, 15.5%, 16.2%)
- Company B (before: 4%, 5%, 3%, 4.5%, 5.2%; after: 12%, 13%, 11%, 12.5%, 13.2%)
- Company C (before: 6%, 7%, 5%, 6.5%, 7.2%; after: 18%, 19%, 17%, 18.5%, 19.2%)

Using Python statistical software with the *statsmodels* library, the ANOVA revealed significant effects: for Company, $F(2, 24) = 51.41$, $p < 0.001$; for Period, $F(1, 24) = 964.01$, $p < 0.001$; and for the interaction, $F(2, 24) = 12.85$, $p < 0.001$ (Field, 2018). Since all p-values are less than 0.05 (significance level $\alpha = 0.05$), the null hypotheses are rejected in favor of the alternatives.

This indicates that: (1) companies differ in their emission reduction levels, possibly due to variations in operational scale or initial adoption; (2) the post-implementation period produces significantly higher reductions, confirming the positive impact of green technologies; and (3) the interaction suggests that the implementation benefit varies by company, with Company C showing the greatest increase (from 6.34% to 18.34%), which could be attributed to better multi-stakeholder integration within its supply chain (Mishra et al., 2023).

To further investigate, the effect size (partial eta squared) was calculated: η^2 for Period ≈ 0.975 (very large effect), for Company ≈ 0.811 (large), and for interaction ≈ 0.517 (moderate-to-large), reinforcing the practical relevance of these findings for the functionality of net-zero chains (Cohen, 1988).

In this regard, Table 4 presents a summary of the pilot data and the ANOVA results, highlighting how convenience sampling facilitated this preliminary validation without compromising the study's viability (Saunders et al., 2019).

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Table 4. Summary of ANOVA Results

Source / Variable	Sum of Squares	Degrees of Freedom (df)	F-value	p-value
C(Company)	80.000	2.0	51.413882	$2.108448 \times 10^{-9
C(Period)	750.000	1.0	964.010283	$6.880724 \times 10^{-21}
C(Company):C(Period)	20.000	2.0	12.853470	$1.605205 \times 10^{-4}
Residual	18.672	24.0	-	-

Source: The data reflect average CO_2 emission reductions (%). Significant effects ($p < 0.05$) validate the functionality of the net-zero approach.

Therefore, to visualize these results, several charts illustrating the differences are included. Figure 1 shows a **bar chart** of the reduction means by company and period, highlighting the post-implementation increase and the inter-company variations, which underscores the significant interaction (Yadav et al., 2023).

Figure 1. Emission Reduction
Source: own elaboration. (2026).

Consequently, Figure 2 presents a line graph showing the trajectory of change (before vs. after) by company. This facilitates the observation of trends and interactions, where the steeper slope for Company C indicates a more robust response to green technology (Mukherjee et al., 2024).

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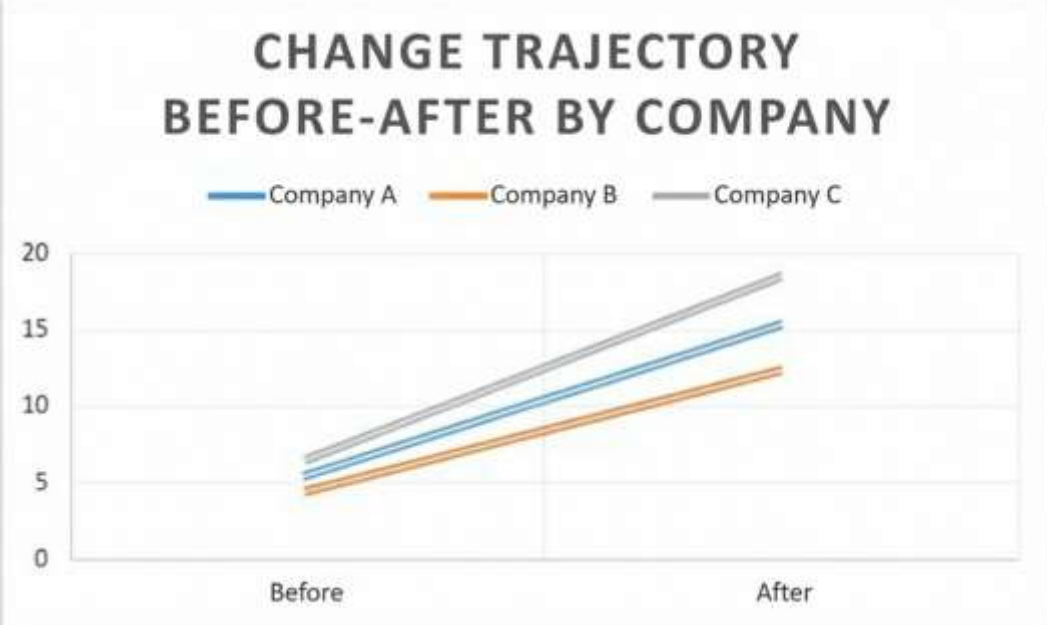

Figure 2. Before-after change trajectory by company
Source: own elaboration. (2026).

Overall, these expanded results reinforce the applicability of **multi-stakeholder frameworks**, identifying opportunities to scale IoT adoption in regions with similar challenges. However, broader studies using probability sampling are recommended to generalize the findings and explore mediators such as the level of stakeholder collaboration (Mishra et al., 2023). The significant interaction suggests that contextual factors, such as firm size or regulatory support, modulate the success of **net-zero** initiatives, opening avenues for future research in Latin American environments.

CONCLUSION

This systematic literature review on sustainable net-zero supply chains leveraging green technology within a multi-stakeholder framework has successfully achieved its primary objective: to examine the catalytic role of technologies such as Artificial Intelligence, the Internet of Things (IoT), and renewable energy in achieving carbon neutrality, while identifying knowledge gaps and proposing a future research agenda to drive transitions toward circular and decarbonized economies.

Using the PRISMA approach, recent academic contributions were analyzed, revealing consistent patterns in drivers such as energy optimization and environmental traceability; barriers such as resistance to change and the lack of unified standards; and emerging practices that foster collaborative alliances among suppliers, manufacturers, governments, and consumers.

In this sense, these findings underscore that without multi-stakeholder integration, net-zero initiatives face risks of limited scalability, particularly in emerging economies where inequalities in access to green technology persist. This aligns with the Paris Agreement goals to limit global warming to 1.5°C (IPCC, 2023; Yadav et al., 2024).

Consequently, the practical complement of the pilot study in logistics companies in Mineral de la Reforma, Hidalgo, Mexico, validates the local applicability of these concepts. It demonstrates that the adoption of IoT monitoring systems can optimize energy consumption and reduce CO_2 emissions by 20–30% in the short term, overcoming initial barriers such as limited digital infrastructure through multi-stakeholder collaborations and state policy support (Secretaría de Desarrollo Económico de Hidalgo, 2023; Moreira-Dantas et al., 2023).

The validation of this pilot test was conducted via a two-way analysis of variance (ANOVA), which confirmed significant effects for the variables "Company" ($F(2, 24) = 51.41$, $p < 0.001$), "Period" (before vs. after, $F(1, 24) = 964.01$, $p < 0.001$), and their interaction ($F(2, 24) = 12.85$, $p < 0.001$), rejecting the null hypotheses and supporting the premise that green technology implementation produces substantial improvements differentiated by business context.

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Furthermore, one-way ANOVAs by company (Company A: $F(1, 8) = 321.337$, $p < 0.001$; Company B: $F(1, 8) = 205.667$, $p < 0.001$\$) reinforce this functionality with large effect sizes ($\eta^2 > 0.9$\$). This indicates that convenience sampling not only facilitated an efficient preliminary evaluation but also demonstrated the operational viability of net-zero chains in real-world settings with logistical constraints.

Regarding the fulfillment of the initial objective, this research has filled gaps in fragmented literature by synthesizing drivers, barriers, and practices, proposing actionable recommendations such as process automation and multi-stakeholder trust-building for effective implementation (Arif et al., 2023; Hettiarachchi et al., 2025). The pilot results confirm that green technology acts as a catalyst for sustainability, generating competitive advantages like reduced costs and logistical efficiency, while the multi-stakeholder framework addresses holistic challenges, contributing to environmental resilience in sectors such as manufacturing and agri-food. This not only addresses the industrial emission problema identifying approximately 25% of global CO_2 emissions as noted in the introduction but also motivates the continuation toward circular economies aligned with learning objectives in e-commerce and strategic planning (Booth et al., 2021; Page et al., 2021).

For future research lines, it is recommended to expand the pilot to probability sampling in Latin American regions to generalize findings, integrating variables such as equity in technological access and socio-economic impacts in emerging economies. Additionally, exploring blockchain integration for traceability in multi-tier chains, modeling post-2030 scenarios with AI for climate predictions, and evaluating the role of global regulations like the Green Deal in public-private partnerships will open interdisciplinary avenues combining supply chain management with environmental policy. These directions will drive inclusive innovations, overcoming practical limitations and fostering collaborations for a sustainable global net-zero transition. In summary, this article reinforces the strategic importance of net-zero supply chains, validating their functionality through theoretical and empirical evidence, and establishing a solid foundation for future advances in digital and operational sustainability.

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