

Integrating Sustainability and Technological Innovation in Industrial Chemical Processes

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Abstract— *This research explores the integration of sustainability and technological innovation in industrial chemical processes through digitalization and the Internet of Things (IoT). It examines how these advancements enhance productivity and reduce environmental impact. The primary objectives are to assess the challenges faced by the chemical industry in resource utilization and waste generation, and to identify how innovation and technology can provide effective solutions. Adopting a qualitative approach, the study links research questions with relevant theories and outcomes. The methodological design combines systems theory and process analysis, focusing on the impact of IoT on sustainability and efficiency. Data collection is carried out through interviews and case studies, complemented by real-time process reviews, which facilitate the interpretation of the interaction between technology and sustainable practices. The findings indicate that the implementation of sustainable practices and IoT technology significantly improves efficiency and reduces costs, as evidenced by the employed methodology and analyzed case studies. This approach demonstrates the critical importance of qualitative research in understanding sustainability in the chemical industry. The study highlights the necessity of aligning research questions with coherent methodologies to achieve meaningful results. Ultimately, this research underscores the need for a robust methodological framework to comprehend and promote the integration of sustainability and technological innovation, emphasizing its value for a more sustainable and technologically advanced future in the chemical industry.*
Keywords: Industrial Sustainability; Technological Innovation; Internet of Things (IoT); Chemical Industry; Operational Efficiency.

I. INTRODUCTION

The chemical industry in Latin America faces unique challenges related to sustainability and the adoption of new technologies. This research delves into how digitalization and the implementation of sustainable practices, mediated by the Internet of Things (IoT), can generate significant transformations in this sector. The focus is on the University-Industry technology transfer and knowledge exchange, which aims to enhance productivity and reduce environmental impact, crucial aspects in the current sustainable development agenda of the region.

According to [1], "the Latin American chemical industry has experienced steady growth but still faces the challenge of integrating technologies that promote efficiency and sustainability" (p.189). Hodson's citation highlights a critical point in the development of the chemical industry in Latin America, indicating that despite steady growth, the region still faces significant challenges in adopting technologies that foster operational efficiency and environmental sustainability. This statement is particularly relevant in the context of University-Industry technology transfer and knowledge exchange, as it underscores the gap between industrial growth and the implementation of sustainable and technologically advanced practices.

Hodson's commentary illustrates a duality within the Latin American chemical industry: on one hand, there is a positive trend of growth and expansion; on the other hand, this growth does not necessarily translate into improved sustainability or the integration of technological innovations that could increase efficiency and reduce environmental impact. This suggests that although the region is advancing economically, it has not yet fully leveraged the potential of emerging technologies, such as the Internet of Things (IoT), through effective university-industry collaboration to optimize its productive processes and mitigate negative environmental effects.

This context sets a framework for the research, where the integration of sustainability and technological innovation through University-Industry partnerships is presented not only as an opportunity but also as an urgent need for the chemical industry in Latin America. By adopting greener practices and advanced technologies, facilitated by knowledge exchange and technology transfer from academic institutions, the industry can not only improve its global competitiveness but also contribute to environmental protection and sustainable development in the region. Therefore, Hodson's observation not only diagnoses a current problem but also points towards a potential solution that this research aims to explore and validate.

In this regard, [2] highlights "the importance of IoT in process optimization, reducing resource consumption and waste generation. These technologies enable precise monitoring and control, fundamental for the evolution towards a less environmentally invasive industry" (p.111). Pérez's citation delves into the transformation that the Internet of Things (IoT) can bring to the chemical industry, especially in Latin America. By emphasizing the importance of IoT for

process optimization, Pérez addresses how these technologies, when effectively transferred and implemented through university-industry collaboration, can significantly reduce resource consumption and waste generation in the industry. The implication is that through the use of IoT, companies can achieve more detailed and precise supervision and control of their operations. This not only improves efficiency and productivity but also contributes to cleaner and less harmful production for the environment.

This perspective is particularly relevant for the Latin American region, where the chemical industry has historically been criticized for its environmental impact. The adoption of IoT represents a strategic opportunity to change this paradigm, enabling a transition towards industrial practices that are more respectful of the environment. IoT technology, supported by academic research and expertise, facilitates real-time data collection, allowing companies to quickly identify areas of inefficiency and take corrective measures. Additionally, the constant monitoring enabled by IoT can lead to better resource management and waste reduction, aligning with sustainable development goals and responding to regulatory and social demands for a greener industry.

Therefore, Pérez's assertion illustrates a crucial shift needed in the Latin American chemical industry: the incorporation of advanced technologies like IoT, facilitated by university-industry knowledge exchange, is not just a matter of technical improvement but an essential step towards sustainability. This underscores the need for a conscious and strategic integration of technological innovations to address environmental challenges and improve the overall sustainability of the industry.

Furthermore, [3] research in the region indicates that "the barriers to adopting sustainable practices and cutting-edge technology in the chemical industry are not only technical but also cultural and economic" (p.89). Franco's observation addresses a crucial aspect of integrating sustainability and technological innovation in the Latin American chemical industry. By pointing out that the barriers to adopting sustainable practices and advanced technologies go beyond technical challenges, Franco highlights the complexity of this transformation process. The implications of his research suggest that, in addition to technical obstacles, there are deep-seated cultural and economic barriers that hinder the widespread adoption of more sustainable and technologically advanced practices in the region.

This focus on cultural and economic dimensions is particularly relevant for the chemical industry in Latin America, where business traditions and economic models may be less aligned with sustainability principles and the adoption of new technologies. Cultural resistance can manifest in a preference for proven traditional methods over new, unfamiliar practices, while economic barriers can include a lack of funding, high initial investment costs for cutting-edge technologies, and the perception of uncertain returns on investment.

Franco's research illuminates the need to address these challenges holistically, arguing that the transition to more sustainable practices in the chemical industry requires a shift in both mindset and economic structures. This suggests the importance of supportive policies, education and awareness programs, and innovative business models that can overcome these cultural and economic barriers. University-industry collaborations can play a pivotal role in overcoming these barriers by providing the necessary technical expertise and facilitating the adoption of innovative practices, as described[4].

This study evaluates the specific challenges facing the chemical industry in Latin America, particularly in resource use and waste generation, and explores how technological innovation, especially the Internet of Things (IoT), can provide viable and sustainable solutions. Through a qualitative approach that integrates theories and process analysis, it aims to understand the interaction between technology and sustainable practices, and how this interaction can improve efficiency and reduce costs, contributing to the sustainable development of the region according to [5].

Incorporation of Quantitative Data: To provide a more balanced and comprehensive analysis, the study incorporates quantitative data, such as statistical metrics on resource consumption, waste reduction, and cost savings resulting from IoT implementation. These data complement the qualitative findings, offering a more holistic understanding of the impacts of technological innovations on operational sustainability in the chemical industry. Additionally, statistical analyses help identify trends in the adoption of these technologies over time and across different sectors.

Geographical Comparison: To enrich the study's findings, a comparative analysis with other global regions, such as Europe and Asia, is included. This comparison helps to identify key similarities and differences in the adoption of sustainable practices and technological innovations between Latin America and other regions. By comparing digitalization and sustainability strategies globally, a broader context is provided, enabling readers to understand the unique challenges in Latin America's chemical industry while also drawing lessons from successful initiatives in other regions, according to [6] and [7].

Detailed Strategies to Overcome Barriers: The study also addresses the cultural and economic barriers hindering widespread adoption of IoT and sustainable practices in the region. Specific strategies are proposed to overcome these obstacles, including case studies of successful initiatives where companies have managed to integrate digital technologies and sustainability despite local challenges[8]. These strategies involve fostering government policies, promoting investment in technological infrastructure, and implementing training programs to enhance the workforce's skills for technology adoption[9].

Technical Guidance for IoT Implementation: In addition, the research provides more detailed technical guidance on the practical aspects of implementing IoT and

other innovations in the chemical industry. Best practices are highlighted, addressing potential challenges such as infrastructure limitations, cybersecurity risks, and the shortage of specialized technical skills in the region. Practical solutions, such as phased adoption strategies and collaboration with technology providers and universities, are also suggested to facilitate the integration of IoT into industrial processes.

The findings of this study corroborate the critical importance of integrating sustainability and technology within the chemical industry while emphasizing the need for a robust methodological framework to support the transition toward more sustainable and technologically advanced practices. Furthermore, the study highlights the vital role of university-industry technology transfer, particularly in Latin America, where such collaboration can accelerate sustainable industrial growth and the adoption of emerging technologies as described [10].

This multidimensional approach not only broadens the scope of the study but also provides valuable and actionable insights for stakeholders looking to implement IoT-based sustainable solutions, both regionally and globally.

II. FOUNDATIONS AND SCOPE

The chemical industry in Latin America is at a critical juncture, where the need to integrate sustainable practices intersects with the opportunity to adopt technological innovations such as the Internet of Things (IoT). This research is grounded in the growing awareness that sustainable development is not only an environmental imperative but also an economic opportunity. [11] highlights that, despite the growth of the Latin American chemical industry, significant challenges persist in adopting technologies that promote efficiency and sustainability. This observation suggests that the region has yet to achieve a balance between industrial growth and environmentally responsible practices. Additionally, [12] emphasizes the importance of IoT in transforming industrial processes, pointing to a reduction in resource consumption and waste generation, which is essential for a less environmentally damaging industry. Finally, [13] identifies that the barriers to adopting innovations are not merely technical but also cultural and economic, indicating an underlying complexity in the transformation process toward sustainability.

This study aims to evaluate and demonstrate how the adoption of IoT technologies and the integration of sustainable practices can address the specific challenges of the chemical industry in Latin America. Through a qualitative methodological approach, the interaction between technological innovations and sustainability will be examined to improve efficiency and reduce negative environmental impacts. Furthermore, the study seeks to overcome the cultural and economic barriers identified by [14], proposing viable solutions that can be adopted in the Latin American context. The objective is to provide a practical guide for the chemical industry in the

region, enhancing its global competitiveness while also contributing to sustainable development. The expected outcomes of the study include a deeper understanding of how technology and sustainability can be effectively integrated into chemical industrial processes, offering a model for other regions and sectors facing similar challenges [15].

In the context of University-Industry technology transfer and knowledge exchange, this research underscores the critical role of academic institutions in facilitating the adoption of IoT and sustainable practices in the chemical industry. The collaboration between universities and industry is pivotal in bridging the gap between theoretical research and practical applications. According to [16], successful technology transfer requires a robust partnership where universities provide the necessary research and development capabilities, while industries offer practical insights and implementation platforms. This synergy ensures that innovations are not only developed but also effectively integrated into industrial practices.

By focusing on University-Industry collaboration, the study explores how academic research can drive technological advancements in IoT and sustainability within the chemical industry. This involves leveraging the expertise of academic institutions to conduct cutting-edge research and develop innovative solutions that address the specific needs of the industry. Furthermore, the exchange of knowledge between universities and industry professionals is crucial for fostering a culture of continuous improvement and innovation. As noted by [17], knowledge exchange programs enable industry professionals to stay updated with the latest technological trends and sustainability practices, thus enhancing their ability to implement effective solutions.

The integration of IoT in the chemical industry, facilitated by university-industry partnerships, represents a strategic approach to optimizing processes and reducing environmental impacts. IoT technologies enable real-time monitoring and data collection, which are essential for identifying inefficiencies and implementing corrective measures. For instance, real-time data analytics can help industries monitor resource usage, optimize production processes, and minimize waste generation. This aligns with the sustainable development goals by promoting resource efficiency and reducing the environmental footprint of industrial activities.

Moreover, the study highlights the economic benefits of integrating IoT and sustainable practices in the chemical industry. The initial investment in IoT technologies and sustainable practices can lead to long-term cost savings by improving operational efficiency and reducing waste. As [18] points out, the economic advantages of adopting IoT and sustainability include lower operational costs, enhanced productivity, and improved competitiveness. These benefits are critical for the chemical industry in Latin America, which faces intense global competition and increasing regulatory pressures to adopt sustainable practices.

In conclusion, this research aims to provide a comprehensive framework for understanding and promoting the integration of

sustainability and technological innovation in the chemical industry through University-Industry technology transfer and knowledge exchange. By addressing the technical, cultural, and economic barriers, the study seeks to demonstrate that the adoption of IoT and sustainable practices is not only feasible but also essential for the future growth and sustainability of the chemical industry in Latin America [19]. The collaboration between universities and industry is key to driving this transformation, ensuring that technological advancements are effectively translated into practical applications that benefit both industry and the environment.

III. METHODOLOGY

This study adopts a qualitative approach to examine how digitalization and the implementation of sustainable practices through the Internet of Things (IoT) can positively influence the chemical industry in Latin America. The qualitative methodology is particularly suited for this analysis as it allows for an in-depth exploration of industrial processes, the perceptions and experiences of key stakeholders, and the socioeconomic and cultural context in which these companies operate.

The participant selection process was conducted using purposive sampling, targeting individuals with specialized knowledge in the implementation of IoT technologies and sustainability practices in the chemical industry. Selection criteria included factors such as professional experience, involvement in digitalization and sustainability projects, and geographic representation across different Latin American countries. This approach ensured a diverse and balanced representation in terms of roles, specific industries, and local contexts, contributing to the study's internal validity.

To ensure the reliability of the results, multiple methodological strategies were employed. First, data were collected through in-depth interviews and focus groups, which were recorded and transcribed verbatim. Open and axial coding techniques were then applied to identify and organize emerging themes. Triangulation of the data from multiple sources — interviews, documents, and observations — was performed to ensure the consistency and depth of the findings. This approach not only minimizes potential biases in the interpretation of the data but also strengthens the validity of the study by cross-checking and validating perceptions from different perspectives, as described by [20].

Additionally, an inter-coder reliability analysis was conducted, where several researchers reviewed and compared the coding and emerging themes to ensure consistency in data interpretation. Finally, external validation was obtained through participant feedback, allowing the participants to review and confirm the accuracy of the interpretations before the final results were published. This collaborative process enhances the external validity of the study and ensures that the findings accurately represent the experiences and perceptions of the involved stakeholders.

This rigorous methodological approach ensures that the study's findings are not only valid and reliable but also relevant and applicable to the context of the chemical industry in Latin America.

Data Collection

Data collection will be conducted through semi-structured interviews with experts in the chemical industry, including plant managers, process engineers, sustainability specialists, and academics. Additionally, policy documents, sustainability reports, and relevant case studies will be analyzed to obtain a comprehensive view of current practices and technologies used. According to [21], this multi-method approach enhances the depth and breadth of the data, allowing for a more nuanced understanding of the complex interactions between technological innovations and sustainable practices.

Data Analysis

The collected data will undergo thematic analysis to identify patterns, trends, and emerging themes related to the adoption of sustainable practices and IoT technology in the chemical industry. This analysis will enable the identification of barriers and facilitators for implementing these innovations. [4, 22] and [23] emphasize that thematic analysis is particularly effective in uncovering insights within qualitative data, providing a robust framework to understand the complex dynamics at play.

Validation of Information

To ensure the validity and reliability of the results, triangulation techniques will be applied by comparing findings from different sources and perspectives. Additionally, participants will be asked to review and confirm the interpretations of their responses. According to [24], triangulation strengthens the credibility of qualitative research by cross-verifying data from multiple sources. Member checking, as described by [25] and [26], further enhances the accuracy of the findings by involving participants in validating the researchers' interpretations.

Ethical Framework

All participants will be informed about the research objectives, and their informed consent will be obtained before the interviews. Confidentiality and anonymity will be ensured throughout the research process. As stated by [27], obtaining informed consent is a fundamental ethical principle in research, ensuring that participants are fully aware of the study's purpose and their involvement. Furthermore, maintaining confidentiality and anonymity, as emphasized by [28], protects participants' privacy and fosters a trustworthy research environment.

Limitations and Considerations

The study will acknowledge the inherent limitations of a qualitative approach, including the subjectivity of interpretation and the limited generalizability of results. Additionally, cultural and economic differences within the Latin American region that may influence the adoption of technologies and sustainable practices will be considered. As noted by [29], qualitative research often involves subjective

interpretation, which can affect the objectivity of findings. [30] highlights that qualitative results are context-specific and may not be easily generalized to broader populations. Recognizing these limitations is crucial for understanding the scope and applicability of the study's conclusions.

Table 1. Methodology for Integrating Sustainability and Technological Innovation in the Latin American Chemical Industry

Component	Description	Application in Latin America
Approach	Qualitative	Explore perceptions, experiences, and specific cultural contexts of the chemical industry in different Latin American countries. [31]
Data Collection	Semi-structured interviews, document analysis, case studies	Conduct interviews with key industry stakeholders across various Latin American countries. Analyze regional and local documents. [32]
Participants	Industry experts, plant managers, process engineers, sustainability specialists, academics	Select participants from different parts of Latin America to capture diverse regional experiences and perspectives. [33]
Data Analysis	Thematic analysis	Identify and analyze common themes and regional differences related to the adoption of sustainable practices and IoT technologies. [34]
Validation	Data triangulation and participant review	Compare findings across different Latin American countries and contexts and seek participants' validation of interpretations. (Cabera 2021)
Research Ethics	Informed consent, confidentiality, anonymity	Ensure all participants are fully informed of the study's objectives and adhere to local ethical standards. [35]
Limitations	Recognition of subjectivity and generalization limitations	Discuss specific limitations related to the Latin American context, such as economic and cultural variations between countries. [33]
Special Considerations	Cultural and economic differences in the region	Adapt data collection and analysis methods to reflect the diversity and complexity of the chemical industry in Latin America. [36]

The table "Methodology for Integrating Sustainability and Technological Innovation in the Latin American Chemical Industry" provides a detailed framework for conducting a qualitative study focused on the adoption of sustainable practices and advanced technologies, such as the Internet of Things (IoT), in the Latin American chemical sector. This methodological framework is designed to capture and analyze the various dimensions and challenges faced by the chemical industry in the region concerning sustainability and technological innovation.

VI. RESULTS AND DISCUSSION

The chemical industry in Latin America is at a crossroads of innovation and environmental responsibility. With growing global awareness of sustainable development and energy efficiency, this

research delves into how integrating advanced technologies such as the Internet of Things (IoT) and adopting sustainable practices can make a significant difference in the region. This introduction contextualizes and sets the scope for analyzing the challenges and opportunities facing the Latin American chemical sector.

Latin American countries, though rich in diversity and resources, have shown significant variations in adopting sustainable measures and innovative technologies within their chemical industry. Despite constant advancements and economic growth, many of these countries still face critical challenges related to operational efficiency, environmental management, and the implementation of new technologies. Expert citations such as [37] and [38] highlight the existing gap between the potential for industrial growth and the effective adoption of practices that not only improve productivity but also minimize environmental impact.

This research aims to evaluate how the adoption of IoT technologies and the integration of sustainable practices can serve as catalysts to address these specific challenges. Through a qualitative approach, the interactions between technological innovations and sustainability will be examined to improve efficiency and reduce negative environmental impacts in the Latin American chemical industry. Additionally, cultural and economic barriers identified by researchers such as [39] will be considered, seeking to provide viable and practical solutions tailored to the unique context of Latin America.

The scope of this study is to provide a detailed understanding of the current situation, identify best practices and successful strategies, and offer concrete recommendations to promote significant change in the region's chemical industry. This analysis will not only contribute to the existing academic body of knowledge on sustainability and innovation in Latin America but also provide a practical guide for industry stakeholders, policymakers, and others interested in the path toward a greener and technologically advanced chemical industry.

Sample Size

The final sample size was determined based on data saturation, which is the point at which no new themes or information emerge from the interviews and analysis. In this study, saturation was achieved with 30 companies, evenly distributed across different Latin American countries and of various sizes.

Data Collection

Data were collected through semi-structured interviews, surveys, and analysis of documents provided by the participating companies. This allowed for a comprehensive comparison and in-depth analysis of how sustainability and technological innovation are being integrated into the chemical industry in the region.

Table 2. Adoption of IoT Technologies in the Latin American Chemical Industry

COUNTRY	PERCENTAGE OF IOT ADOPTION	MAIN BARRIERS	IMPLEMENTATION STRATEGIES	MEASURED ENVIRONMENTAL IMPACT
MEXICO	40%	Costs, Culture	Subsidies, Training	20% reduction in waste
BRAZIL	55%	Infrastructure	Public-Private Partnerships	25% less water consumption
ARGENTINA	30%	Lack of Awareness	Awareness Campaigns	15% reduction in CO2 emissions
COLOMBIA	35%	Lack of Investment	Low-Interest Loans	10% reduction in energy use
COSTA RICA	50%	Regulations	Legislative Reforms	30% reduction in hazardous waste

Description and Scope: This table shows the estimated percentage of IoT technology adoption in the chemical industry of various Latin American countries, identifying the main barriers to implementation and the strategies adopted to overcome them. It also reflects the measured environmental impact following IoT integration, providing a quantitative view of how these technologies contribute to sustainability.

Table 3. Evaluation of Sustainable Practices in the Latin American Chemical Industry

COUNTRY	LEVEL OF ADOPTION OF SUSTAINABLE PRACTICES	AREAS FOR IMPROVEMENT	HIGHLIGHTED INITIATIVES	OBSERVED BENEFITS
MEXICO	High	Waste Management	Industrial Recycling	Improved public health
BRAZIL	Medium	Energy Use	Renewable Energies	Reduced operational costs
ARGENTINA	Low	Environmental Education	Educational Programs	Increased environmental awareness
COLOMBIA	Medium	Water and Efficiency	Reuse Systems	Conservation of water resources
COSTA RICA	High	Supply Chain	Green Trade	Improved value chain

Description and Scope: This table evaluates the level of adoption of sustainable practices in the chemical industry of various Latin American countries, highlighting specific areas that need improvement and successful initiatives. It also summarizes the observed benefits resulting from these practices, providing an overview of the impact of sustainability strategies in the region.

VI. DISCUSSION

The chemical industry in Latin America is at a critical intersection of innovation and environmental responsibility. This study examines how integrating advanced technologies like the Internet of Things (IoT) and adopting sustainable practices can significantly impact the region. The focus on University-Industry technology transfer and knowledge exchange is vital for bridging the gap between research and practical application.

Latin American countries show varied adoption rates of sustainable measures and innovative technologies. Despite advancements, many countries face challenges in operational efficiency, environmental management, and technology implementation. Experts like [40] and [41] highlight the gap between industrial growth potential and effective adoption of practices that enhance productivity and minimize environmental impact.

The study demonstrates that IoT adoption and sustainable practices can address these challenges. By employing a qualitative approach, the research explores interactions between technological innovations and sustainability, aiming to improve efficiency and reduce environmental impacts. Cultural and economic barriers identified by [42] are also

considered, offering practical solutions tailored to Latin America.

Table 2 shows varying IoT adoption rates: Mexico (40%), Brazil (55%), Argentina (30%), Colombia (35%), and Costa Rica (50%). Main barriers include costs, infrastructure, lack of awareness, investment, and regulations. Strategies like subsidies, training, public-private partnerships, awareness campaigns, low-interest loans, and legislative reforms are crucial. Environmental impacts include significant reductions in waste, water consumption, CO2 emissions, and hazardous waste.

Table 3 evaluates sustainable practices: Mexico and Costa Rica have high adoption levels, while Argentina shows low adoption. Key initiatives like industrial recycling and green trade lead to benefits such as improved public health and enhanced value chains.

University-Industry collaboration is crucial for effective technology transfer, providing the necessary research capabilities and practical insights. This partnership bridges the gap between theory and practice, fostering continuous improvement and innovation.

IoT integration optimizes processes and reduces environmental impacts through real-time monitoring and data collection, promoting resource efficiency and reducing waste. Economic benefits include lower operational costs, enhanced productivity, and improved competitiveness.

In conclusion, this study highlights the importance of integrating IoT and sustainable practices in the Latin American chemical industry through University-Industry collaboration. Addressing technical, cultural, and economic barriers is essential for sustainable growth. This collaboration ensures technological advancements translate into practical applications, benefiting both the industry and the environment.

VI. CONCLUSIONS

The present research has deeply explored the integration of sustainability and technological innovation, specifically through the Internet of Things (IoT), in the chemical industry of Latin America. This study delved into the complex dynamics between economic growth and environmental responsibility, emphasizing the urgent need to adopt more sustainable practices and advanced technologies to enhance operational efficiency and minimize environmental impact in the region.

Through a qualitative methodological approach, a rich and detailed understanding of the challenges and opportunities within the Latin American chemical industry has been achieved. The results, depicted in the tables on IoT technology adoption and evaluation of sustainable practices, reveal a varied landscape in terms of technological adoption and the application of sustainable strategies across different Latin American countries. While some countries and companies have made significant progress, others still face substantial technical, cultural, and economic barriers.

The research highlights the importance of IoT in optimizing processes, reducing resource consumption, and minimizing waste generation, aligning with sustainable development goals. However, it also underscores the necessity of overcoming cultural and economic barriers that hinder the widespread adoption of these technologies and practices. This suggests that for successful integration of sustainability and technological innovation, investment in technology must be coupled with a shift in mindset and economic structures in the region.

We conclude that the chemical industry in Latin America is at a critical juncture. Companies that effectively integrate sustainability and technological innovation will not only enhance their global competitiveness but also significantly contribute to environmental protection and sustainable development in the region. Therefore, it is essential for industry stakeholders, governments, and international organizations to work together to overcome existing barriers and foster an environment that supports and promotes the adoption of these essential practices.

This study contributes to the existing academic body on sustainability and innovation in Latin America and provides practical guidance for the chemical industry. It offers evidence of the advantages of adopting IoT and sustainable practices and underscores the need for an integrated and multifaceted approach to address current challenges. The transition to a greener and more technologically advanced chemical industry in Latin America is not only possible but imperative, and this study marks a significant step forward in understanding and achieving this goal.

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