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INTEGRATING CARBON AND ENVIRONMENTAL ACCOUNTING INTO SUSTAINABILITY REPORTING: A SYSTEMATIC LITERATURE REVIEW

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ABSTRACT

Objective: This study aims to analyze the integration of Carbon Accounting (CA) and Environmental Accounting (EA) in Sustainability Reports and their impact on company performance in terms of finance, operations, reputation, and governance, with a focus on the contribution of accounting system harmonization to sustainable value and the challenges of its implementation.

Research Design & Methods: Using a Systematic Literature Review (SLR) approach guided by the PRISMA protocol, this study synthesizes findings from 57 peer-reviewed journal articles published between 2002 and 2025 and indexed in Scopus.

Findings: The results show a significant upward trend in research related to CA, EA integration, especially after 2020, driven by the adoption of global frameworks such as IFRS S2, GRI Standards, and EU CSRD. Empirical evidence shows that CA/EA integration positively affects corporate performance, especially in large companies with adequate technological and financial capacity. However, challenges remain, including inconsistencies in measurement methods, limitations in data reliability, and reporting practices that are symbolic rather than substantive.

Implications & Recommendations: This study emphasizes the importance of global harmonization of sustainability reporting standards, standardization of ESG audits, and strengthening institutional capacity, especially in emerging markets, so that CA/EA data is integrated into strategic management and investment decisions to drive real sustainability transformation.

Contribution & Value Added: This study confirms that CA, EA integration unifies financial and environmental accountability, and strengthens the theory and practice of sustainability accounting towards transparency and transition to a low-carbon economy.

Keywords: Carbon Accounting, Environmental Accounting, Sustainability Reporting, Corporate Sustainability, ESG Disclosure.

JEL codes: M41, Q56, Q01
Article type: research paper

INTRODUCTION

The integration of Carbon Accounting (CA) and Environmental Accounting (EA) into Sustainability Reporting (SR) has become imperative amid the urgency of the climate crisis, where business entities are required to increase transparency and accountability for their environmental impact. There is a deep global awareness of climate change as an existential risk to the economy and society (Anjani et al., 2025). Environmental accounting practices such as carbon accounting,

environmental management accounting, and life cycle costing have been observed to support climate mitigation by internalizing environmental externalities, for example by measuring the carbon emissions of products or assigning costs to pollution, which have been noted to support more sustainable decision-making (Madaleno et al., 2023; Mishra et al., 2024; Velte, 2023). In the digital age, rising carbon emissions due to industrial and technological development have made climate change a major concern, demanding greater accountability from the corporate sector. Although Environmental Accounting (EA) has long focused on environmental costs, performance, and disclosure of the overall impact of corporate activities, Carbon Accounting (CA) has emerged as a specialization that provides sharper and more specific metrics (Ogunode, 2022).

ESG disclosure, found in sustainability or integrated reports, serves as a communication strategy for climate change initiatives, as it increases transparency regarding corporate climate risks, carbon footprints, and mitigation measures, thereby enabling stakeholders to evaluate companies' sustainability commitments (Ferjančič et al., 2024; Gabr and ElBannan, 2025; Hoang, 2023). The central issues currently faced are inconsistency, lack of data reliability, and low comparability of sustainability reports globally (Zubaida et al., 2025). This challenge is compounded by the existence of multiple measurement standards (GHG Protocol, ISO, SBTi, regional systems), creating methodological variation, flexibility, and ultimately hindering global comparability (McDonald et al., 2024). The limited availability of global data for GHG inventories also leads to high measurement uncertainty (Marlowe and Clarke, 2022). As a result, sustainability reports are often symbolic or selective, with companies only highlighting their strengths without transparently disclosing their weaknesses (Hattab and Mardini, 2025).

The main impetus for CA/EA integration comes from capital markets and global regulators. The International Sustainability Standards Board (ISSB) published IFRS S1 and IFRS S2 in June 2023, marking a new era of sustainability disclosure in capital markets (IFRS, 2023). This standard creates a global common language for the disclosure of climate-related risks and opportunities, which explicitly aims to provide data useful for investment decisions. IFRS S2 fundamentally raises expectations for the quality of Carbon Accounting data and fully integrates the recommendations of the Task Force on Climate-related Financial Disclosures (TCFD) (IFRS, 2023).

This convergence is particularly important because IFRS S2 explicitly refers to a universal measurement standard, namely the GHG Protocol Corporate Standard, as the basis for GHG accounting (Huckins, 2024). This recognition reinforces the GHG Protocol's position as the common standard that companies should use, whether under European (CSRD) or US (SEC Rules) regulations, or voluntary initiatives such as the Global Reporting Initiative (GRI) and the Science-Based Targets initiative (SBTi). Thus, global standards now require climate information to be viewed as material financial data, reported alongside financial statements, which is expected to improve data quality, governance, and companies' access to capital. Therefore, this study analyzes how these standardization requirements affect corporate accounting practices.

There is still a lack of in-depth research on how greenhouse gas (GHG) emissions data is integrated into corporate monitoring and strategic decision-making mechanisms (Marlowe and Clarke, 2022). Without integrating emissions data into capital allocation processes or annual fiscal policies, for example through the concept of carbon budgets as a climate mitigation effort, these measures tend to be symbolic and do not produce real change. This study highlights three key issues in the development of Carbon Accounting (CA) that require further attention, namely the integration of carbon data into managerial decision-making, the harmonization of global reporting standards, and the reliability and auditability of environmental data. Specifically, this study aims to analyze the integration of Carbon Accounting (CA) and Environmental Accounting (EA) into Sustainability Reports, and assess its impact on various dimensions of corporate performance, including financial, operational, reputational, and governance.

The main objective is to identify the extent to which harmonization of accounting systems can contribute to the creation of sustainable value, while revealing institutional and methodological challenges that hinder effective implementation. Theoretically, this research contributes through a synthesis of the paradigm shift from the dominance of Legitimacy Theory to the pressure of

Institutional Theory, especially with the advent of global standards. From a practical standpoint, this research offers a future development agenda that focuses on the standardization of reliable climate data, the application of independent assurance, and the integration of carbon information into managerial accounting metrics and corporate budgeting systems. This approach is expected to serve as a guideline for accounting practitioners and academics in building new competencies that are relevant in the era of data-driven sustainability reporting.

LITERATURE REVIEW

Conceptualization of Environmental Accounting (EA) and Carbon Accounting (CA)

Environmental Accounting (EA) serves as a broader tool for disclosing the impact of corporate activities, with the aim of improving accountability, transparency, and corporate reputation (Nasution et al., 2025). The focus of EA includes identifying and allocating environmental costs incurred in operations, such as waste disposal and pollution fines. However, the complexity of modern climate challenges has led to specialization in Carbon Accounting (CA). CA is defined as a specific innovative approach to measuring, reporting, and reducing greenhouse gas (GHG) emissions generated by entities, making it a vital instrument in efforts to achieve global carbon neutrality (Syam et al., 2024).

CA is based on three internationally adopted emission scopes: Scope 1, direct emissions from sources owned or controlled by the company (e.g., fuel combustion); Scope 2, indirect emissions from purchased energy; and Scope 3, other indirect emissions from the supply chain, such as suppliers and final consumers (Samuel et al., 2024). Functionally, the difference between EA and CA creates integration challenges. EA, which is related to Environmental Costs, can have a negative impact on short-term profitability due to compliance costs (Idris et al., 2025). Conversely, strategically measured Carbon Accounting that focuses on material efficiency can have a direct and positive impact on cost efficiency, profitability, and financial statement transparency (Zubaida et al., 2025). Good carbon accounting transparency has also been shown to increase investor and market confidence, demonstrating that CA is transitioning from a mere cost of compliance to a value driver (Idris et al., 2025).

Theoretical Framework for Sustainability and Climate Disclosure

Historically, research on sustainability reporting has been dominated by Legitimacy Theory, Stakeholder Theory, and Organizational Theory (Hazaea et al., 2023). Legitimacy theory states that organizations strive to maintain their operations within boundaries and norms that are acceptable to society (social contract) (Ogunode, 2022). Within this framework, companies tend to report environmental information voluntarily to maintain their image and social legitimacy. Reporting driven by this theory is often symbolic or selective, aiming to highlight strengths without revealing weaknesses.

Institutional Theory and Stakeholder Theory often intersect and are complementary, explaining how social, environmental, and market pressures shape reporting practices (Martens and Bui, 2023). The Systems Theory further provides a framework for understanding Carbon Accounting as an integrated information system (Carbon Accounting Information System), in which elements such as emissions data, emission factors, and reporting interact to achieve sustainability and environmental governance objectives (Astuti and Difinubun, 2025).

Carbon and Environmental Accounting Methods and Standards

Measurement standardization is key to successful CA, EA integration. The most widely used global standard is the GHG Protocol Corporate Standard, which establishes the basis for GHG accounting and divides emissions into Scope 1, 2, and 3. This protocol has been widely adopted by various initiatives such as the Global Reporting Initiative (GRI) and the Science-Based Targets initiative (SBTi) (Huckins, 2024). In addition, new regulations such as the European Commission's CSRD and even SEC rules in the United States refer to the GHG Protocol, strengthening its position as a common standard for corporate GHG accounting. In the field of Environmental Management

Accounting, various techniques are used to identify and allocate environmental costs internally. One of the main methods is Material Flow Cost Accounting (MFCA), which is standardized through ISO 14051 and focuses on material losses and hidden costs such as energy and CO_2 emissions (Let et al., 2010). Other methods such as Life Cycle Assessment (LCA) and Environmental Activity-Based Costing also play an important role in assessing the overall environmental impact of a product (Niccolucci et al., 2001). The success of CA and EA depends heavily on the ability to link material efficiency data from MFCA with external reporting such as the GHG Protocol for Scope 1 and 2 emissions.

IFRS S2 fully integrates the recommendations of the Task Force on Climate-related Financial Disclosures (TCFD) and explicitly refers to the GHG Protocol. This signals a shift driven by capital markets to make climate information material financial data, rather than merely Corporate Social Responsibility (CSR) data (IFRS, 2023). It is hoped that the implementation of IFRS S1 and S2 will improve data quality, strengthen governance, and facilitate companies' access to capital, reducing duplication and inconsistency in voluntary reporting (International Financial Reporting Standards, 2023). This transformation requires accounting professionals to acquire new knowledge and skills in measuring, reporting, and advising on climate risk. However, findings show that accounting curricula at many universities still have very limited references to climate skills, creating a gap between capital market demands and professional readiness (Khosa et al., 2024).

METHODS

This study used the Systematic Literature Review (SLR) method by adopting the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol to ensure transparency, objectivity, and replicability in the literature synthesis process. This approach was chosen because it is capable of comprehensively compiling and analyzing research related to Carbon Accounting (CA) and Environmental Accounting (EA) and their integration into sustainability reporting. The SLR procedure began with the identification of articles through reputable academic databases such as Scopus and Web of Science using a combination of keywords such as "carbon accounting," "environmental accounting," "sustainability reporting," "IFRS S2," and "GHG protocol" to capture the dynamics of global developments and regulatory pressures. Articles found were selected based on inclusion criteria (peer-reviewed scientific articles focusing on the corporate context) and exclusion criteria (books, theses, non-peer-reviewed proceedings, or industry reports). The next stage involves screening and verifying eligibility by reading the title, abstract, and full text to ensure relevance to the topic of CA/EA integration. Next, data extraction is carried out, covering the theoretical basis, methodology (MFCA, LCA, GHG Protocol), geographical and industrial context, and identified research gaps. The results of this process are synthesized qualitatively to map research trends, implementation challenges, and the direction of theoretical development from Legitimacy Theory towards Institutional and Stakeholder Theory, thereby producing an in-depth understanding and an up-to-date research map in the field of Sustainability Accounting.

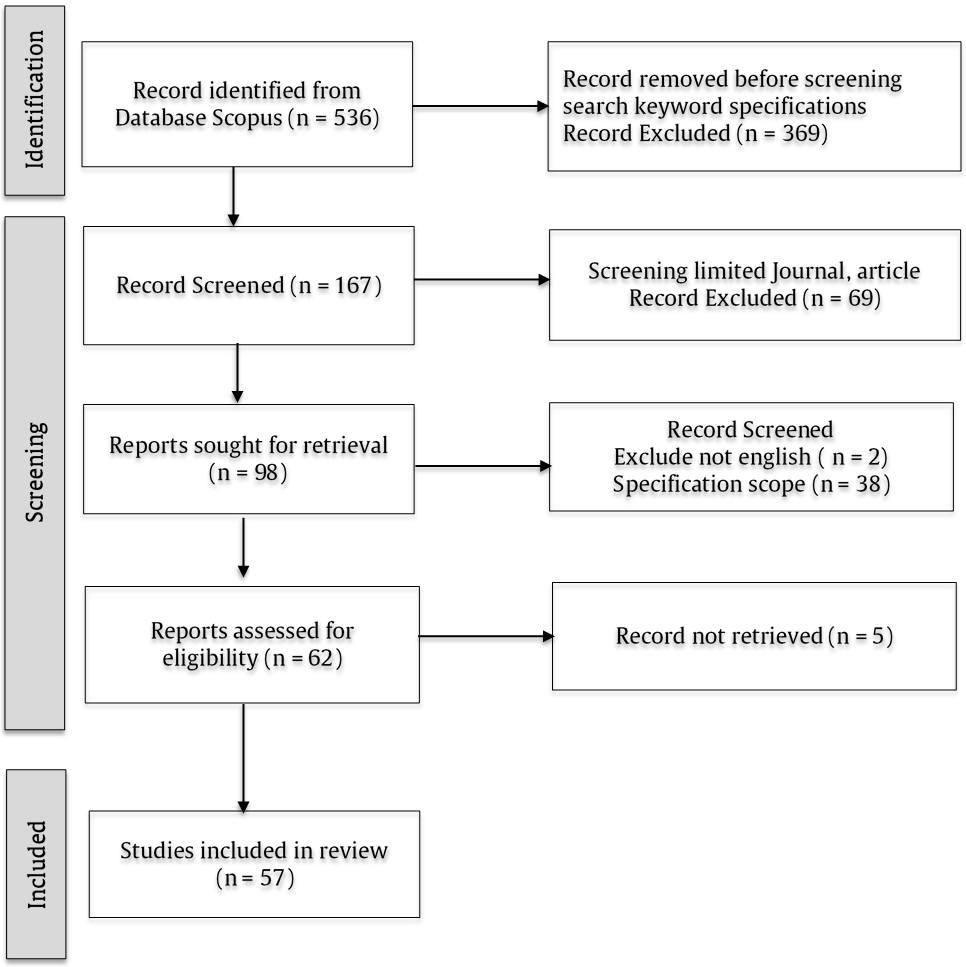

Figure 1. PRISMA flow chart

RESULT

Based on 57 studies reviewed in detail, research trends on "Integrating Carbon and Environmental Accounting into Sustainability Reporting" show a rapid increase from 2002 to 2025. In the early period (2002–2010), publications were still limited to only 0–2 articles per year, indicating low attention to the issue of carbon accounting. However, from 2011 to 2016, the number of publications began to increase in line with the emergence of global awareness of climate change and the adoption of reporting frameworks such as GRI and GHG Protocol. A significant surge occurred in the period 2021–2025, when publications increased sharply from 5 to 10 articles per year, triggered by the introduction of global standards such as IFRS S2, which encourages mandatory sustainability reporting. This trend reflects a shift in research focus from voluntary reporting to an integrated, regulation-based accounting approach, and confirms the position of this topic as a strategic area in the development of sustainability accounting and corporate climate governance.

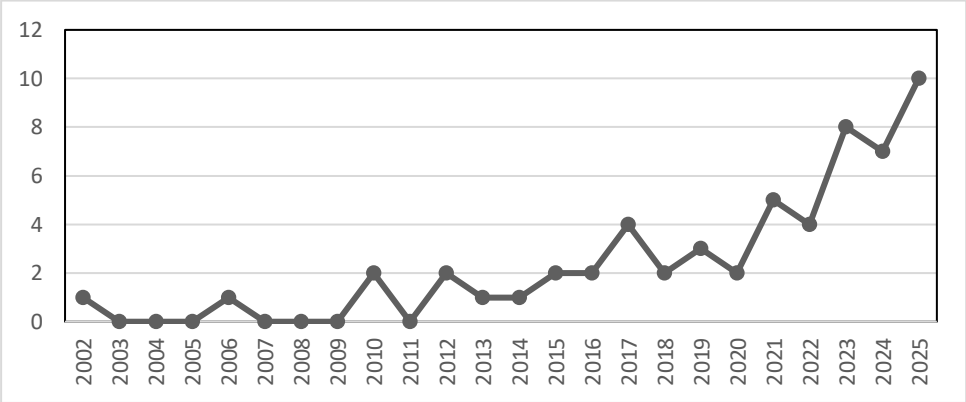

Figure 2. Research Development Trend Over the Years Based on Scopus Data

Based on the results of geographical analysis of Scopus data, there is a relatively concentrated distribution in developed countries with strong environmental policy support. The United States ranks first with 9 publications, indicating academic and institutional leadership in developing carbon reporting and sustainability integration, particularly through the adoption of ESG disclosure-based reporting practices and climate risk management. Spain and the United Kingdom ranked second with six publications each, demonstrating Western Europe's active involvement in sustainability reporting research in line with the European Green Deal policy and Corporate Sustainability Reporting Directive (CSRD) standards.

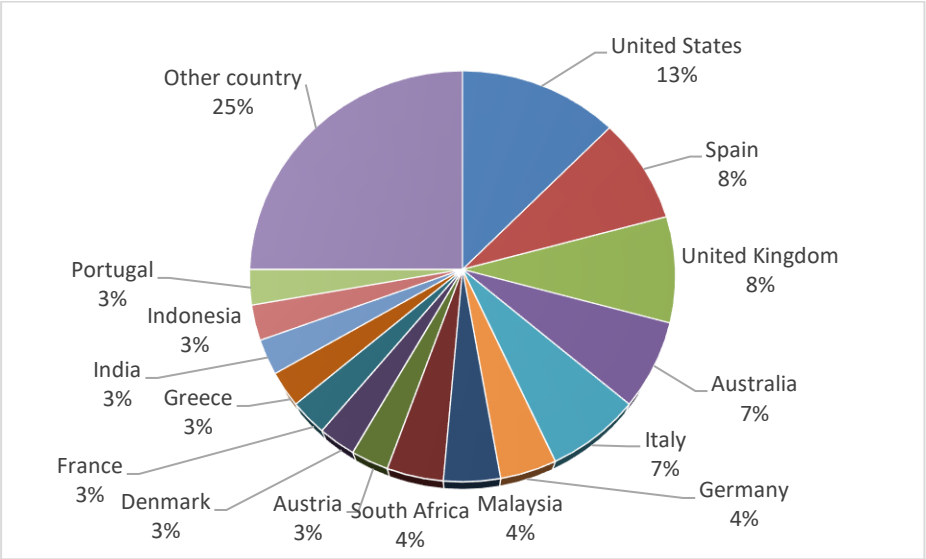

Figure 3. Geographical Distribution of Publications

Countries such as Australia and Italy also stand out with five documents each, confirming their focus on regulation-based environmental reporting and interdisciplinary research between accounting and industrial ecology. Meanwhile, Germany, Malaysia, and South Africa each contributed three publications, demonstrating the growing participation of developing countries and the Global South region, which are beginning to align accounting practices with national emissions policies. In addition, countries such as Austria and Denmark are beginning to play a role in the context of carbon policy and green innovation. Overall, this geographical pattern illustrates the dominance of research from countries with established sustainability regulatory systems and high institutional capacity. However, the emergence of contributions from developing countries such as Malaysia and South Africa indicates a new trend toward the globalization of carbon and environmental accounting topics, which has the potential to expand their academic relevance and application in various economic contexts.

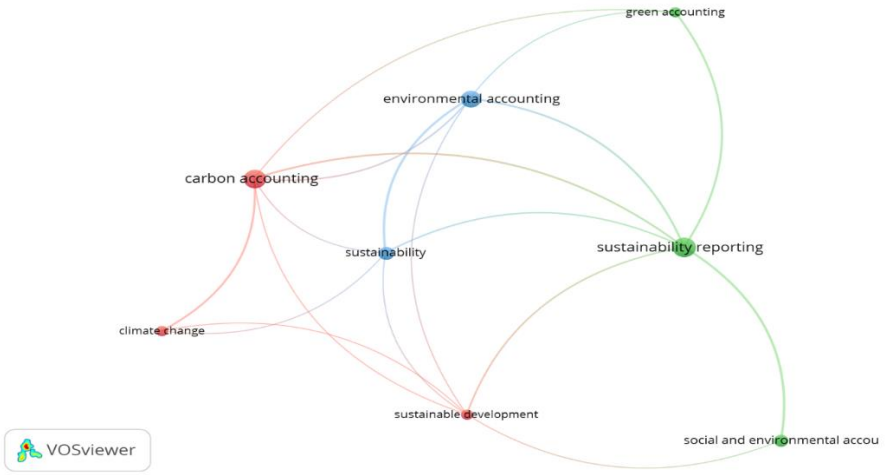

Figure 4. Keyword Correlation Map

The keyword map illustrates the conceptual relationship between carbon accounting, environmental accounting, and sustainability reporting in academic literature. The visualization shows that sustainability reporting is the central node connecting all the main concepts, indicating that sustainability reporting serves as an integrative framework for various environmental and social accounting approaches. Carbon accounting occupies an important position in the red cluster, demonstrating its role as a key instrument in measuring emissions and mitigating climate change, which contributes to sustainable development goals. Meanwhile, environmental accounting acts as a bridge between carbon accounting and sustainability reporting, as it provides a broader framework for quantifying environmental impacts, including resource efficiency and waste management. Green accounting and social and environmental accounting broaden the scope of sustainability reporting by emphasizing the internalization of environmental costs and aspects of corporate social accountability. In addition, the concept of sustainability and sustainable development, which is positioned at the end of the network, represents the final result of this entire integration process, namely realizing corporate sustainability and long-term balance between the economy, society and the environment. Overall, the relationship between these keywords confirms that the integration of Carbon Accounting and Environmental Accounting into Sustainability Reporting does not merely expand the scope of reporting, but reflects a transdisciplinary effort in unifying climate impact measurement, environmental valuation, and social accountability as a unified reporting system that is transparent and oriented towards sustainable development.

The Effect of Carbon Accounting and Environmental Accounting Integration on Company Performance

The integration of Carbon Accounting (CA) and Environmental Accounting (EA) has been proven to have a broad and significant impact on various dimensions of company performance, both in terms of financial, operational, reputational, and sustainability governance. In general, the results of the study indicate that the integration of environmental accounting systems has a significant positive impact on company financial performance, especially in large-scale entities with adequate capacity and resources ($\beta = 0.618$, $p < 0.001$), compared to small and medium enterprises ($\beta = 0.234$, $p < 0.05$) (Hasanuddin and Natsir, 2025). This finding confirms that an organization's ability to allocate investments for technology, environmental audits, and sustainability reporting determines the effectiveness of CA and EA implementation on long-term profitability and efficiency (Maama and Gani, 2022; Mondal et al., 2024).

The integration of Life Cycle Assessment (LCA) and GHG Protocol-based carbon accounting plays a crucial role in identifying the largest emission sources, measuring reduction opportunities, and supporting production efficiency and compliance with national low-carbon policies (Mulya et

al., 2025). In the agrifood and extractive industries sectors, this practice not only reduces production costs, but also strengthens the company's reputation as a player committed to decarbonization and sustainability (Anguiano-Santos et al., 2024; Sukmadilaga et al., 2023; Walenta, 2021). In the urban context, the integration of green accounting and ESG is an important pillar in increasing public accountability and transparency, where measurable sustainability reporting strengthens the legitimacy of local governments and the competitiveness of local economies (Greiling and Grüb, 2014; Sklavos, Zournatzidou, Ragazou, Spinthiropoulos, et al., 2025; Ştefănescu, 2021).

Studies also show that the integration of green accounting indicators with ESG disclosures has resulted in innovations such as the Greenwashing Risk Index, an objective tool for assessing the credibility of sustainability reporting and mitigating reputational risk (Sklavos, Zournatzidou, Ragazou, and Sariannidis, 2025). Through this mechanism, companies can strengthen internal controls and the efficiency of decarbonization investment decisions, as well as transform business operations towards energy efficiency and alignment with the Sustainable Development Goals (SDGs) (Asam et al., 2025; Cihat Onat et al., 2025). Furthermore, CA/EA has proven its ability to translate net-zero commitments into measurable business objectives, strengthening the accountability and auditability of emissions targets so that carbon reporting can now be audited with a level of precision similar to financial reporting (Brander and Bjørn, 2023; Carrión et al., 2025; Easton et al., 2025).

In addition to financial benefits, standardization and harmonization of carbon reporting plays a major role in creating comparability of data between companies, increasing investor confidence, and strengthening the legitimacy of capital markets (Grajales-Gaviria et al., 2023; Luo and Tang, 2023; Pesci et al., 2023; Stachelscheid and Dutzi, 2025). Integration with international frameworks such as GRI, IFRS S1–S2, and ISSB makes sustainability reporting more credible and uniform globally (Anguiano-Santos et al., 2024; Pesci et al., 2023). From a governance perspective, good environmental disclosure is positively related to environmental certification and strong management structures (Mähönen, 2020; Monteiro et al., 2023), while the role of women's participation in reporting also strengthens the transparency and ethics of carbon reporting (Fabrício et al., 2022). In the public sector, CA and EA integration also promotes fiscal accountability and transparency of public funding (Herbohn and Henderson, 2002; Ştefănescu, 2021).

However, several studies have shown contextual and heterogeneous effects. The implementation of green accounting can negatively impact profitability if environmental costs such as water and energy are not managed efficiently (Sukmadilaga et al., 2023). Several studies also found that environmental and social reporting is still performative or symbolic, more oriented towards legitimacy than real performance management (Bebbington and Larrinaga, 2024; Cooper and Senkl, 2016; Di Tullio and Rea, 2024; Patten, 2012). The effect of CA and EA integration on financial performance is proven to be weak if it is not supported by good corporate governance and effective internal control mechanisms (Liesen et al., 2015; Maama and Gani, 2022). Similar challenges also arise in the SME sector, where CA and EA integration only provides competitive benefits if implementation costs can be well controlled (Castilla-Polo and Guerrero-Baena, 2023; Corazza, 2017).

From an institutional perspective, regulatory and government policy support is a key factor in successful implementation. Integrating the green taxonomy and strengthening the national legal framework has been shown to increase environmental transparency and sustainability awareness in the industrial sector (O' Reilly et al., 2024; Singh et al., 2017). The regulatory environment and governance of countries also play a role in strengthening ESG practices and carbon reporting at the corporate level (Leong and Hazelton, 2019; Maama, 2021). However, the positive effects on operational efficiency will only be realized if the company has complete data and a consistent reporting system (Gibassier and Schaltegger, 2015; Liesen et al., 2015; Olson, 2010).

On the reputational dimension, the integration of CA and EA increases the legitimacy and public trust in the company, especially through credible non-financial reporting (Bellucci et al., 2019; Krivačić and Janković, 2017; Laine, 2021; Lokuwaduge et al., 2022). Companies that combine socio-environmental reporting with ethical communication demonstrate increased stakeholder

trust and sustainable investment opportunities (Johnson et al., 2020; Mendoza-Flores et al., 2019; Murphy and McGrath, 2013). However, several studies highlight that reputational impacts are not always followed by increased operational efficiency, as many reports do not fully reflect actual environmental performance (Moneva et al., 2006; Patten, 2012).

Overall, findings from the literature indicate that the integration of CA and EA contributes to improvements in a company's energy efficiency, profitability, reputation, and sustainability governance, with the strength of the impact depending on the quality of implementation, regulatory support, and the organization's technological readiness. The strategic implementation of CA and EA not only strengthens a company's position in the global value chain but also makes it an active actor in the transition to a sustainable, low-carbon economy.

Major Challenges and Obstacles

The literature review shows that the implementation of Carbon Accounting (CA) and Environmental Accounting (EA) faces various multidimensional challenges, encompassing technical, institutional, and cultural aspects. These challenges need to be thoroughly understood so that practitioners and policymakers can design more effective reporting standards and corporate practices (Abdalla et al., 2024; Raghupathi et al., 2023). One of the most fundamental obstacles is the lack of standardization and comparability in CA and EA reporting, which leads to inconsistencies between companies, both in the content and methods of disclosure (Alotaibi et al., 2024). Prior to the emergence of the International Sustainability Standards Board (ISSB) standards, companies were free to choose frameworks such as GRI, SASB, TCFD, or national guidelines, which led to fragmented reporting and difficulties in benchmarking across entities (Hazami-Ammar, 2025; Matuszak-Flejszman et al., 2024). This condition is in line with the findings in various studies which show that disharmony in standards and variations in methodologies are the main obstacles in the integration of CA and EA into sustainability reporting (Anguiano-Santos et al., 2024; Bradley and Botchway, 2018; Pesci et al., 2023; Sklavos, Zournatzidou, Ragazou, Spinthiropoulos, et al., 2025; Vallišová et al., 2018).

The absence of uniform global standards puts ESG reporting at risk of becoming a corporate promotional tool rather than a credible transparency instrument, as companies can cherry-pick metrics that are profitable (Tian et al., 2024). This is reinforced by literature findings which show that much CA and EA reporting is still symbolic and legitimacy-oriented, rather than real impact management (Bebbington and Larrinaga, 2024; Liesen et al., 2015; Lokuwaduge et al., 2022; Moneva et al., 2006; O′Reilly et al., 2024; Sklavos, Zournatzidou, Ragazou, and Sariannidis, 2025). Harmonization efforts through regulations and institutions like the ISSB are positive steps, but literature shows that global alignment of reporting practices remains far from ideal. Furthermore, the lack of independent verification and assurance poses a significant challenge to ensuring the credibility and reliability of ESG data (Alotaibi et al., 2024). Many ESG metrics such as carbon footprint and climate risk exposure rely on estimates and assumptions, unlike financial data which is always audited (Madaleno et al., 2023; Tian et al., 2024).

The phenomenon of greenwashing is a serious concern in this context. Some jurisdictions have even implemented anti-greenwashing regulations to ensure the honesty and accuracy of reporting (Meqbel et al., 2025). The SLR results show that weaknesses in audit and assurance standards exacerbate reputational risks, reduce investor confidence, and weaken the sustainability reporting function (Greenham, 2010; Olson, 2010; Patten, 2012) To improve this situation, the researchers recommend the implementation of standardized ESG audit procedures and clear measurement guidelines to improve data quality and comparability (D′Amato et al., 2021; Mishra et al., 2024).

From an institutional perspective, the dominant challenge is the lack of integration between sustainability accounting and financial decision-making. Many companies still treat environmental reporting as a separate entity from financial reporting, resulting in CA and EA information not being fully reflected in business strategy or risk management (Madaleno et al., 2023). As a result, climate risks are not always reflected in asset valuations or financial risk analysis (Abdalla et al., 2024). Full

integration through integrated reporting is believed to be the solution, because it allows simultaneous assessment of environmental and financial performance (Alotaibi et al., 2024; Principale and Pizzi, 2023). However, its implementation faces technical challenges in quantifying the economic value of climate resilience, as well as difficulties in ensuring that finance departments share responsibility for environmental metrics (Noja et al., 2024).

Another common challenge is limited organizational resources and capacity, particularly for small and medium-sized enterprises in developing countries. These barriers include a shortage of expertise, high implementation costs, and supply chain complexity in collecting comprehensive ESG data (Cihat Onat et al., 2025; Hasanuddin and Natsir, 2025; Mondal et al., 2024). Many companies are only able to meet the minimum requirements, resulting in reporting that is shallow and less informative (Alotaibi et al., 2024). Regulators are trying to balance ambition with practical capacity through phased policies and a simple framework for MSMEs (An, 2023; Ngo et al., 2023). However, implementing quality environmental accounting still requires significant investment in systems and human resources, which is not yet fully affordable without clear economic incentives.

Globally, differences in regulatory and economic capacity across countries give rise to the risk of regulatory arbitrage, where companies in jurisdictions without ESG obligations can avoid reporting for short-term gains, but lose the trust of global investors (Matuszak-Flejszman et al., 2024). This gap underscores the need for international cooperation and capacity building in developing countries to ensure that ESG reporting does not become a new trade barrier or administrative burden (Tian et al., 2024). Furthermore, the research highlights the conceptual challenge of distinguishing between symbolic reporting and real impact. While transparency is important, sustainability reporting is only meaningful if it drives changes in corporate behavior. Several studies have found that high ESG scores do not necessarily correlate with reduced emissions or improved environmental performance (Madaleno et al., 2023; Yadiati et al., 2024).

Overall, a systematic review of the literature indicates that the main challenges to CA and EA integration fall into four broad dimensions: (1) limited resources and technical expertise; (2) inconsistency and fragmentation of reporting standards; (3) gaps between reporting and actual implementation; and (4) weak institutional infrastructure and regulatory enforcement at the global level. These results are consistent with the findings of cross-country studies showing that despite the convergence of standards and frameworks, significant gaps remain in the quality, consistency, and accountability of environmental disclosures (Abdalla et al., 2024; Dias et al., 2024). Thus, the way forward needs to be directed at harmonizing global policies, increasing institutional capacity, and enforcing credible environmental audits to make the integration of CA and EA not just a symbol of legitimacy, but a real foundation towards measurable and responsible sustainability.

DISCUSSION

The integration of carbon and environmental accounting into sustainability reporting faces fundamental obstacles stemming from misalignment in measurement methodologies, data reliability, and comparability across entities and jurisdictions. Recent literature shows that despite regulatory advances and global standards such as the GHG Protocol, GRI Standards, EU CSRD, and IFRS S1–S2, practices on the ground are still far from harmonized and consistent.

Critical Gap Analysis and Regulatory Implications

Several studies have revealed that differences in measurement methodologies are a major cause of carbon data gaps. For example, Scope 2 reporting practices by chemical and pharmaceutical companies in Europe remain highly heterogeneous. Many companies fail to distinguish between market-based and location-based approaches, resulting in non-transparent emissions reports that are difficult to compare across entities. The use of market-based GHG accounting methods, as this approach has the potential to reduce the accuracy of emissions inventories if not accompanied by a strict causality principle. Furthermore, reporting systems such as the GHG Protocol and the Science Based Targets initiative (SBTi) are considered to still have technical friction in determining target limits, methodologies, and monitoring mechanisms to achieve net-zero (Carrión et al., 2025). As a

result, there is an inconsistency between global decarbonization targets and companies' internal accounting.

The next obstacle relates to the reliability and verification of environmental data. Sklavos, Zournatzidou, Ragazou, and Sariannidis (2025) study of 365 European financial institutions found a significant disparity between ESG disclosure and actual environmental performance. The Greenwashing Risk Index (GWI) developed shows that many companies achieve high ESG scores but have poor records on green accounting indicators such as environmental penalties and resource intensity. This suggests that reporting remains largely symbolic and not substantive in supporting data-driven decision-making. In the context of developing countries, Adeyeye et al. (2023) observed that limited emission factor and activity data make it difficult to calculate institutional carbon footprints in Africa. Reliance on global secondary data without local adjustments increases measurement uncertainty, thereby reducing the reliability and credibility of carbon reporting in the Global South.

Furthermore, cross-country and cross-sector comparability remains a critical issue in the integration of carbon and environmental accounting. The study of Anguiano-Santos et al. (2024) shows that although EU Directive 2014/95/EU (NFRD) has encouraged mandatory sustainability reporting, flexibility in its implementation has led to highly variable levels of disclosure across member states such as Italy, Germany, the Netherlands, and Spain. Differences in legal and business cultures have also widened the harmonization gap between countries, so efforts to build comparable reporting systems remain limited. Beyond regulations, standards such as the GRI and IFRS S2 still exhibit overlap and varying interpretations. The high flexibility of the GRI standards creates ambiguity in reporting, while the newly adopted IFRS S2 is still in its early stages of implementation and has not yet fully integrated with traditional financial accounting systems. As a result, many companies struggle to consistently integrate sustainability information into their financial reports.

The gap also arises from differences in organizational capacity and data infrastructure. Larger companies have more sophisticated environmental accounting systems integrated with strategic decision-making, while SMEs still struggle with limited resources, data access, and technical expertise. As a result, SME sustainability reports tend to be descriptive and immeasurable, widening the reporting quality gap between large and small entities. Meanwhile, existing carbon management information systems are unable to provide useful data for operational decision-making. Regulations such as the EU CSRD and the SEC Climate Disclosure Rule focus more on external transparency than on internal requirements for emissions management, which hinders the creation of synergies between reporting systems and corporate decarbonization strategies (Anguiano-Santos et al., 2024).

The combination of methodological gaps, data limitations, and a lack of harmonization of standards creates epistemological challenges for integrating carbon accounting into sustainability reporting. This creates the risk that sustainability reporting will become a mere compliance ritual, rather than a strategic management tool. The literature also warns that without a reliable and comparable measurement system, global efforts towards net zero will lose their scientific and economic credibility. Therefore, many researchers emphasize the need to redefine auditability and performativity in sustainability reporting so that reporting not only fulfills symbolic expectations but also contributes significantly to environmental and social transformation.

The Carbon Measurement Gap in Corporate Decision Making

Although carbon accounting has emerged as a key instrument in sustainability reporting, various literatures indicate that there is still a fundamental gap between carbon measurement and its application in corporate strategic decision-making. This phenomenon is referred to as the missing link, where emissions data generated by reporting systems are not optimally utilized to support business strategies, investments, or sustainable innovation. As a result, carbon accounting functions more as a formal compliance tool than as a strategic management instrument capable of driving the transformation to a low-carbon economy.

Most research confirms that current carbon accounting practices remain reactive to external pressures such as regulation and reputational demands. Reporting systems designed around rules like the EU CSRD and the SEC Climate Disclosure Rules emphasize transparency and public reporting rather than leveraging carbon data for operational decision-making. As a result, carbon reporting remains a primarily external accountability mechanism, rarely used to improve efficiency or internal innovation.

This gap is also evident in the lack of integration of carbon accounting across a company's value chain. Many organizations still limit reporting to Scope 1 and Scope 2, omitting Scope 3, which covers emissions from upstream and downstream activities. This results in strategic decision-making not reflecting all climate risks and opportunities in the supply chain. In contrast, Cihat Onat et al. (2025) case study of a public transportation company shows that the implementation of comprehensive Carbon Accounting and Reporting (CAR) can drive significant changes in strategy, including the identification of emission hotspots, energy efficiency, and sustainable collaboration across the value chain.

On the other hand, conventional accounting frameworks are also considered incapable of effectively supporting decarbonization decisions. Therefore, a carbon measurement model adapted from financial accounting systems, where carbon emissions are treated like amortizable assets and liabilities, is needed. This model provides a new perspective for integrating carbon reporting with strategic financial management, but also shows the limitations of traditional accounting systems in capturing real environmental value. This links carbon information to investment decision-making, ensuring that reporting is not merely administrative but also creates managerial value for innovation and operational efficiency. Reporting standards such as the Global Reporting Initiative (GRI) and IFRS S2 Climate-Related Disclosures have the potential to strengthen the strategic link between carbon accounting and corporate management. However, the high flexibility in GRI implementation often creates ambiguity in determining materiality and impact measurement, thus hampering the integration of environmental data into corporate strategy.

The disconnect between economic and environmental value is also at the root of this strategic gap. Companies that have received sustainability awards have not demonstrated a significant relationship between green accounting practices and increased economic value (EVA). This situation indicates that carbon accounting has not yet fully become part of a company's strategic value creation model. Thus, although carbon reporting has become the global norm, there is still no clear mechanism for linking this information to investment decisions, innovation, and long-term strategy.

Overall, this strategic linkage gap demonstrates that the transformation to a low-carbon economy remains declarative. The resulting emissions data has not been fully utilized to guide corporate strategies for creating sustainable value. To close this missing link, companies need to integrate carbon accounting into managerial decision-making systems through harmonization of standards, digitalization of reporting systems, and strengthening of analytical capacity. With these steps, carbon accounting can evolve from being a mere reporting tool into a strategic instrument that plays a direct role in creating sustainable economic and environmental value.

Global Regulatory Convergence and Its Impact on Accountants

The convergence of global regulations in sustainability reporting marks a major shift in the accounting world towards integration between financial and non-financial reporting. Harmonization of various international standards such as EU CSRD, ISSB with IFRS S1 and S2, and GRI aims to create a sustainability reporting framework that is consistent, transparent, and globally comparable. This phenomenon opens up opportunities for increasing the accountability and credibility of ESG information, but also poses significant challenges for the accounting profession, which is now required to master multidisciplinary skills, including climate risk analysis, carbon footprint measurement, and the application of scientific methodologies such as the GHG Protocol and Life Cycle Assessment (LCA).

Accountants are no longer only tasked with reporting financial data, but also act as guardians of the integrity of sustainability reporting, ensuring data reliability and preventing greenwashing practices. However, regulatory flexibility, such as the NFRD and CSRD in Europe, still gives rise to varying interpretations across countries, which actually hinders the desired harmonization. This convergence also shifts the institutional position of the accounting profession from merely financial controllers to agents of social and environmental legitimacy in the global governance system.

The impact is not only on professional practice, but also on the education and competency development of accountants. Studies in Europe demonstrate the need for curriculum transformation toward sustainability-based, applied learning, with technology mastery, data analysis, and environmental understanding as core competencies. Despite providing strategic value, global harmonization also brings ethical and economic dilemmas, accountants must maintain objectivity amidst management pressure, while companies, especially SMEs, face the burden of implementing sustainability reporting and auditing systems.

CONCLUSION

The results of the study show that the integration of Carbon Accounting (CA) and Environmental Accounting (EA) into Sustainability Reporting plays an important role in improving company performance in terms of energy efficiency, profitability, social legitimacy, and sustainability governance. Findings from 57 studies show that companies that strategically implement CA and EA are able to strengthen reporting transparency, gain investor confidence, and improve operational efficiency and green innovation. This integration also helps companies meet global regulatory requirements such as IFRS S1–S2, GRI Standards, and EU CSRD, which are increasingly encouraging decarbonization and sustainability-based reporting practices.

However, the implementation of CA and EA still faces a number of obstacles, including fragmentation of reporting standards, non-uniformity of emission measurement methodologies, limited human resources and technology, and weak independent verification of ESG data. In the context of developing countries, limited institutional capacity and data infrastructure mean that environmental reporting does not fully reflect actual sustainability impacts. Therefore, the effectiveness of CA/EA integration on company performance depends heavily on regulatory support, technological readiness, and strong governance.

This research emphasizes the importance of global harmonization of sustainability reporting standards to reduce fragmentation and increase comparability across sectors and countries. For policymakers, efforts are needed to strengthen credible ESG audit and assurance systems so that reporting is not merely symbolic but can support sustainable investment decisions. For companies, these results provide a foundation for integrating CA and EA comprehensively into strategic decision-making processes, not simply as compliance tools. For academics and the accounting profession, the implication is the need to develop multidisciplinary competencies in sustainability accounting, including the ability to measure climate risk, manage emissions data, and assess the socio-economic impacts of decarbonization policies. Overall, the integration of CA and EA is not merely a reporting instrument, but a strategic foundation for corporate sustainability transformation. Targeted implementation supported by strong regulations will accelerate the transition to a transparent, accountable, and equitable low-carbon economy.

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