

Application of the GHG protocol in management accounting: Case studies of global technology companies

Primena protokola o emisiji gasova staklene bašte u upravljačkom računovodstvu: Studije slučaja globalnih tehnoloških kompanija

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Received / Rad primljen: 06.11.2025, Accepted / Rad prihvaćen: 08.12.2025.

Abstract: In today's business world, the managing of CO₂ emissions is becoming an increasingly important element of sustainability strategies, while management accounting stands out as a central mechanism for their effective implementation. This paper explores how management accounting can contribute to the control and reduction of greenhouse gas (GHG) emissions, using the case studies of Apple and Microsoft as examples. In this context, we rely on the GHG protocol which is an internationally recognized standard for measuring emissions. The result show that the integrating emissions into internal management processes enables companies to identify key sources of emissions, optimize costs, and support strategic decisions in the area of decarbonization. Apple has achieved significant emissions reductions through supply chain transformation, the use of renewable energy, and the incorporation of carbon indicators into procurement processes and product design. On the other hand, Microsoft, despite its advanced reporting mechanisms and internal carbon tax, faces challenges in managing extensive Scope 3 emissions due to the growth of energy-intensive infrastructure for cloud and AI. The comparative analysis shows that success in reducing emissions depends on the ability of companies to align their managerial focus with the dominant sources of CO₂. This paper confirms that management accounting enables the transformation of emissions into measurable and financially relevant variables, thereby promoting efficiency, reducing risk, and creating sustainable competitive advantage.

Keywords: management accounting, GHG protocol, CO₂ emissions, sustainability, decarbonization.

Sažetak: U današnjem poslovnom svetu, upravljanje emisijama CO₂ postaje sve važniji element strategija održivosti, dok se upravljačko računovodstvo ističe kao centralni mehanizam za njihovu efikasnu implementaciju. Ovaj rad istražuje na koji način upravljačko računovodstvo može doprineti kontroli i smanjenju emisija gasova staklene bašte, a kao primer prikazane su studije slučaja kompanija Apple i Microsoft. U ovom kontekstu, fokus je na GHG protokolu, koji je međunarodno priznati standard za merenje emisija. Rezultati pokazuju da integracija emisija u interne upravljačke procese daje mogućnost kompanijama da identifikuju ključne izvore emisija, optimizaciju troškova i podršku strateškim odlukama u oblastima dekarbonizacije. Kompanija Apple ostvarila je značajno smanjenje emisija kroz transformaciju lanca snabdevanja, korišćenje obnovljive energije i ugradnju ugljeničnih indikatora u procese nabavke i dizajn proizvoda. Sa druge strane, kompanija Microsoft uprkos naprednim mehanizmima izveštavanja i internoj taksi za emisiju CO₂, suočava se sa izazovima u upravljanju obimnim emisijama povezanim sa Scope 3, usled rasta energetske intenzivne infrastrukture za Cloud i AI. Komparativna analiza pokazuje da uspeh u smanjenju emisija zavisi od sposobnosti kompanija da usklade menadžerski fokus sa dominantnim izvorima CO₂. Rad potvrđuje da upravljačko računovodstvo olakšava transformaciju emisija u merljive i finansijske relevantne varijable, čime se podstiče efikasnost, smanjenje rizika i stvaranje održive konkurentne prednosti.

Ključne reči: upravljačko računovodstvo, GHG protokol, emisija CO₂, održivost, dekarbonizacija.

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INTRODUCTION

The increasing emphasis on digitalization and innovative business practices has enabled organizations to manage internal processes and data more efficiently, providing strong support for managerial accounting systems designed to track and control CO₂ emissions (Brkljač, et al., 2022). Companies now recognize that carbon emissions not only pose environmental and regulatory risks but also represent strategic opportunities. Furthermore, many countries have introduced ecological taxes to reduce GHG emissions (Balaban and Stoiljković, 2023), further underscoring the need for robust managerial accounting tools. This awareness has driven the adoption of decarbonization strategies alongside environmental control mechanisms, such as carbon accounting systems (CASs). Empirical studies indicate that well-designed CASs enhance the effectiveness of carbon strategies by translating organizational objectives into measurable improvements in emissions performance (Bui et al., 2022). Integrating robust accounting systems with proactive carbon strategies enables firms to achieve meaningful reductions in CO₂ emissions, reinforcing the central role of managerial accounting in sustainability efforts.

Over the past decade, the development of environmental management accounting (EMA) has introduced a range of managerial and control instruments that enhance the measurement, oversight, and communication of corporate environmental performance. Although widely acknowledged as critical for corporate sustainability, the practical application of these tools and their effectiveness in improving carbon management remain uneven (Qian et al., 2018). Empirical evidence from multinational firms demonstrates that while many organizations adopt selected EMA tools, only a minority implement comprehensive suites of practices. Tools that support auditing, benchmarking, and control-oriented decision-making significantly influence carbon management and reporting outcomes, reinforcing the importance of managerial accounting in aligning operational actions with sustainability objectives.

Managerial Carbon Accounting (MCA) further extends these principles by providing managers with frameworks to integrate greenhouse gas emissions into internal decision-making processes (Tang, 2025). Unlike financial carbon accounting, MCA emphasizes operational and strategic support, incorporating key elements such as mitigation costs, green investments, carbon budgets, performance evaluation, and internal emissions reporting. By linking emissions to managerial actions, MCA facilitates more effective decarbonization efforts while

maintaining cost control, demonstrating how managerial accounting can serve as a practical tool for both operational efficiency and environmental stewardship.

The relevance of managerial accounting extends beyond the corporate context. Cities, as major contributors to CO₂ emissions, play a pivotal role in implementing mitigation strategies (Brown & MacAskill, 2025). Effective urban carbon management requires accurate and systematic accounting, yet municipal authorities often face constraints in data availability, technical capacity, and financial resources. Approaches such as integrating diverse data sources, visualizing emissions for spatial planning, developing district-level mitigation strategies, and monitoring project-level emissions illustrate how accounting systems can guide sustainable urban decision-making. Moreover, broader socio-ecological awareness is key to sustainability. As Simić (2025) points out, environmental security and social awareness are essential for achieving sustainable development, emphasizing the need for adaptive strategies and harmonizing corporate and social activities with environmental realities. These insights emphasize the broader applicability of managerial carbon accounting as a strategic mechanism for emission reduction.

Practical applications of managerial carbon accounting are evident in industry-specific contexts as well. For instance, Sun et al. (2024) developed a combined carbon and cost accounting model for a liner shipping company operating under the EU Emissions Trading System (EU ETS). By linking CO₂ emissions across voyage stages with operational costs, the model enabled managers to identify cost-effective strategies for emission reduction while maintaining economic efficiency. Similarly, the global review by Hazaea et al. (2022) demonstrates that carbon accounting has evolved into a strategic tool for decision-making and corporate reporting, highlighting the need for standardized methodologies to ensure comparability and reliability of emissions data.

Moreover, integrating carbon accounting with broader resource management enhances managerial decision-making. Wang et al. (2021) shows that tracking natural resource flows through input-output analysis provides critical information for both strategic planning and operational optimization, effectively linking environmental performance with economic outcomes. These examples collectively illustrate that managerial accounting, when properly designed and applied, can serve as a powerful instrument for controlling and reducing CO₂ emissions across organizational and urban contexts.

In line with this perspective, the present study aims to explore how managerial accounting serves as a tool for emission control by examining best practices through case studies and leading frameworks. Specifically, the research presents real-world examples from Apple and Microsoft, demonstrating how these companies have leveraged the Greenhouse Gas (GHG) Protocol and internal managerial accounting systems to achieve measurable reductions in carbon emissions.

1. MATERIALS AND METHODS

In this research, we apply a comprehensive methodological approach that combines case studies, statistical analysis and comparative evaluation. We begin by presenting case studies of leading technology companies, with a particular focus on their greenhouse gas (GHG) reporting practices. Specifically, the authors analyze Apple and Microsoft to illustrate how the principles of managerial carbon accounting and the GHG protocol apply in real organizational settings.

The relationship between accounting and CO₂ has gained increasing importance as greenhouse-

gas emissions have shifted from being perceived solely as an environmental concern to becoming a measurable, reportable, and financially relevant business variable. Contemporary carbon accounting applies established accounting principles - such as measurement, verification, and transparency - to emissions data, enabling organizations to quantify their climate impact using standardized frameworks. Among these, the Greenhouse Gas (GHG) Protocol represents the most widely adopted international methodology for calculating and managing emissions across both private and public entities. It categorizes emissions into three scopes that collectively capture a company's direct and indirect carbon footprint (Table 1). Specifically, Scope 1 encompasses direct emissions from assets owned or controlled by the company, Scope 2 accounts for indirect emissions arising from purchased energy (including electricity, steam, heat, and cooling), while Scope 3 covers all other indirect emissions across the value chain, including those associated with suppliers, customers, and other upstream and downstream activities.

Table 1 - The Greenhouse Gas Protocol (Scope 1, Scope 2 and Scope 3)

Scope 1 Direct emissions	Scope 2 Indirect emissions	Scope 3 Indirect emissions
Direct emissions that are owned or controlled by a company	Indirect emissions that are a consequence of a company's activities but occur from sources not owned or controlled by it	
Emissions from sources that an organization owns or controls directly	Emissions a company causes indirectly that come from where the energy it purchases and uses is produced	All emissions not covered in scope 1 or 2, created by a company's value chain
Example The emissions from burning fuel in the company's fleet of vehicles (if they're not electrically powered)	Example The emissions caused by the generation of electricity that's used in the company's buildings	Example When the company buys, uses and disposes of products from suppliers

Source: <https://www.nationalgrid.com/stories/energy-explained/what-are-scope-1-2-3-carbon-emissions>

By converting emissions into numerical indicators - often linked to explicit carbon prices, regulatory obligations, and market-based mechanisms - CO₂ effectively becomes an economic item that can be treated as a cost, liability, or strategic risk within corporate decision-making processes. This integration enables companies not only to comply with emerging regulatory requirements (such as CSRD, ETS, and sustainability reporting standards) but also to create reliable and audit-ready datasets that support long-term climate strategies. The data obtained, from the GHG reports of Apple and Microsoft companies will be further analyzed using statistical and comparative methods, which enable the identification of similarities, differences and the

best practices in the managerial accounting of carbon dioxide. This approach provides not only a rigorous assessment of corporate performance, but also situates the findings within the broader context of sustainable decision-making.

2. RESULTS AND DISCUSSION

This section examines case studies that demonstrate how companies are implementing greenhouse gas (GHG) management practices within their operations. Emphasis placed on the role of management accounting in supporting greenhouse gas emissions management, improving resource efficiency, and integrating carbon reporting into strategic decision-making and operational perform-

ance. These cases provide a basis for understanding how theoretical frameworks are applied in practice, offering concrete insights into effective decarbonization strategies. Apple and Microsoft are highlighted as leading examples, illustrating how management accounting and the Greenhouse Gas (GHG) Protocol work together to reduce measurable emissions and improve operational efficiency in complex global supply chains.

2.1. Case Study: Apple GHG Protocol

Apple represents one of the most advanced global examples of corporate carbon management, applying the Greenhouse Gas (GHG) Protocol as the foundational framework for quantifying and reporting its emissions. The company systematically measures emissions across all three protocol-defined scopes, enabling a transparent and comprehensive assessment of its carbon footprint. According to the Apple Environmental Progress Report 2025, the company has achieved a reduction of over 60% in total greenhouse gas emissions compared with its 2015 baseline, demonstrating the effectiveness of its managerial accounting systems and decarbonization strategy. Apple's reporting structure ensures that emissions are categorized according to standardized principles, facilitating comparability both across time and with other multinational corporations.

Scope 1: Direct Emissions from Owned and Controlled Sources

Scope 1 emissions include direct outputs from Apple's facilities, testing laboratories, and fleet operations. These emissions have been substantially reduced due to the company's long-term decarbonization initiatives, including the transition to high-efficiency systems, electrification of equipment, and optimization of heating and cooling processes in corporate facilities. Through continuous monitoring and real-time environmental accounting, Apple maintains precise internal control over Scope 1 sources, allowing emissions to be treated as operational performance indicators within managerial accounting frameworks.

Scope 2: Indirect Emissions from Purchased Energy

Scope 2 emissions, stemming from electricity and heating purchased for corporate operations, represent another major component of Apple's carbon footprint. Apple reports that it has reached 100% renewable electricity across its corporate facilities, data centers, and owned retail locations worldwide. This achievement significantly lowered Scope 2 emissions, effectively decoupling operational growth from energy-related carbon output.

Managerial accounting plays a central role in this transition, enabling the identification of high-consumption facilities, cost-benefit evaluations of renewable energy procurement, and integration of carbon metrics into investment decisions.

Scope 3: Value-Chain Emissions

The largest share of Apple's total emissions originates from Scope 3 activities, which include upstream suppliers, downstream product use, logistics, business travel, and end-of-life treatment. In 2024 alone, suppliers participating in Apple's Clean Energy Program generated 17.8 GW of renewable electricity, contributing to substantial reductions in upstream emissions. Apple applies managerial carbon accounting tools to integrate supplier performance metrics into procurement decisions, cost analyses, and long-term climate strategies. By converting value - chain emissions into quantifiable indicators, Apple treats CO₂ output as a strategic economic variable - one that affects procurement cost structures, product design, and supply-chain risk assessments. This approach is consistent with the GHG Protocol's emphasis on capturing the broadest possible emissions boundary, thereby enhancing transparency and accountability.

Apple's carbon accounting is embedded within a broader managerial accounting system that aligns operational, financial, and sustainability objectives. Emissions data are incorporated into internal dashboards, cost-benefit analyses, and capital budgeting models, enabling managers at all levels to evaluate trade-offs between environmental performance and economic efficiency. This integration has facilitated the prioritization of high-impact decarbonization initiatives, such as material substitution, increased product recyclability, and the optimization of logistics networks. By establishing measurable carbon budgets and linking them to performance indicators, Apple ensures that emission-reduction targets influence managerial decision-making rather than remaining isolated within sustainability reporting.

Apple's approach illustrates that managerial accounting is not just a reporting tool but a strategic system that enables measurable emission reductions across all levels of the organization.

The application of GHG Protocol accounting has allowed Apple to:

- enhance transparency and auditability of emissions data;
- support decarbonization planning through standardized performance metrics;
- integrate carbon impacts into resource allocation and innovation processes;

- reduce operational and value-chain emissions at a pace consistent with long-term net-zero objectives.

The Apple case illustrates how a comprehensive carbon accounting system - grounded in the GHG Protocol and supported by managerial accounting tools - can enable measurable reductions in greenhouse-gas emissions. It also demonstrates that managerial accounting serves not only as a reporting mechanism but as a strategic control system that directly supports emission reduction efforts in multinational corporations.

2.2. Case Study: Microsoft GHG Protocol

Microsoft represents one of the world's largest technology companies and a global benchmark in the application of carbon accounting principles grounded in the Greenhouse Gas (GHG) Protocol. The company provides detailed, annually updated disclosures of its direct and indirect emissions, enabling comprehensive assessment of its carbon footprint across Scope 1, Scope 2, and Scope 3 categories. Data for this case study are drawn from the Microsoft Environmental Data Fact Sheet 2025, covering fiscal year (FY) 2024. Microsoft's systematic approach to carbon accounting reflects a high level of methodological rigor, transparency, and alignment with international sustainability standards, allowing emissions to function as measurable managerial variables within internal decision-making systems.

Scope 1: Direct Emissions from Owned and Controlled Sources

Microsoft's Scope 1 emissions for FY 2024 amounted to 143,510 metric tons of CO₂e. These emissions originate primarily from company-owned facilities, backup generators, testing laboratories, and corporate vehicle fleets. The observed level reflects ongoing efforts to reduce fossil-fuel dependency through improvements in energy efficiency, transition to low-carbon equipment, and operational optimization of physical infrastructure. By incorporating Scope 1 emissions into internal monitoring dashboards and performance indicators, Microsoft applies a managerial accounting framework in which direct emissions become quantifiable operational cost drivers.

Scope 2: Indirect Emissions from Purchased Electricity (Market-Based Method)

Microsoft reports 259,090 metric tons of CO₂e under Scope 2 (market-based) for FY 2024. These emissions reflect the environmental impact associated with the generation of purchased electricity used in Microsoft's global facilities and data centers. Although the company procures large volumes of

renewable energy under power purchase agreements, its rapid expansion of energy-intensive cloud infrastructure continues to influence total Scope 2 emissions. Through managerial accounting, energy-related emissions are integrated into long-term investment decisions, enabling the company to evaluate trade-offs between cloud growth, renewable energy procurement, and decarbonization commitments. This supports Microsoft's strategic objective of achieving 100% renewable electricity across its operations.

Scope 3: Value-Chain Emissions

As with many global technology firms, Scope 3 represents Microsoft's dominant emission category. In FY 2024, Scope 3 emissions totaled 15,140,000 metric tons of CO₂e, accounting for more than 97% of the company's total carbon footprint. These emissions stem from upstream and downstream activities across the value chain, including manufacturing of devices by third-party suppliers, transportation and distribution, product use by customers, and end-of-life treatment. Microsoft employs advanced carbon accounting tools to quantify these emissions, following GHG Protocol methodologies for allocation, estimation, and boundary setting. The scale of Scope 3 emissions underscores the strategic importance of incorporating supplier performance metrics, lifecycle assessments, and product-design decisions into managerial accounting systems.

Microsoft's emissions data undergo independent third-party verification, most recently by Deloitte & Touche LLP, ensuring credibility and auditability. The company applies established recalculation policies in cases of methodological updates, acquisitions, divestitures, or expansion of reporting boundaries. This transparent methodological structure aligns with GHG Protocol's core principles - accuracy, consistency, completeness, and comparability - and strengthens the validity of Microsoft's carbon disclosures for both academic analysis and cross-company benchmarking.

Microsoft integrates GHG emissions into its internal management systems, treating CO₂ not only as an environmental metric but as a financially relevant variable that informs cost accounting, risk assessment, supply-chain strategy, capital budgeting, and long-term planning for cloud infrastructure. The company evaluates emissions intensity per revenue unit, models future carbon scenarios, and incorporates internal carbon fees into business-unit planning. This use of managerial accounting tools enables Microsoft to achieve a high degree of internal alignment between operational decisions and its long-term climate goals, including the comm-

itment to become carbon negative by 2030. Microsoft demonstrates that integrating GHG emissions into financial and operational planning allows CO₂ to be treated as a measurable economic variable, aligning sustainability goals with corporate strategy.

Despite reductions in Scope 1 and Scope 2 emissions, Microsoft faces persistent challenges in managing the scale and growth of Scope 3 emissions, which continue to dominate its overall carbon footprint. The company's rapid expansion in cloud computing and AI infrastructure further increases energy demand and upstream manufacturing emissions. Nevertheless, Microsoft's application of GHG Protocol accounting - combined with rigorous verification and integration into managerial accounting - provides a systematic foundation for identifying mitigation opportunities and guiding high-impact sustainability initiatives. The Microsoft case thus illustrates how carbon accounting frameworks can support managerial control mechanisms, enabling firms to balance operational growth with climate-related objectives.

2.3. Comparative Analysis: Apple vs. Microsoft GHG Protocol

A comparison of Apple and Microsoft provides insight into how different business models and managerial accounting frameworks affect the efficiency of greenhouse gas (GHG) management.

Apple and Microsoft, as two of the world's largest technology corporations, demonstrate sophisticated applications of GHG Protocol accounting principles; however, their emissions profiles and managerial responses reveal notable structural and strategic differences. These differences arise from their respective business models, supply-chain configurations, and managerial accounting systems used to monitor and reduce CO₂ emissions.

Apple and Microsoft both operate global infrastructures, yet the composition of their emissions differs substantially. Apple reports a reduction of over 60% in total emissions from its 2015 baseline, while Microsoft's emissions remain dominated by Scope 3, totaling over 15 million metric tons of CO₂e in FY 2024. Apple's emissions structure is strongly influenced by its manufacturing supply chain, but large-scale investments in supplier renewable energy programs (17.8 GW installed in 2024) have significantly mitigated upstream emissions. In contrast, Microsoft's cloud-based business model generates considerable downstream and upstream emissions related to data centers, semiconductor production, and product use.

Table 2 shows a comparative analysis of Apple and Microsoft according to the GHG protocol, including emissions by Scope category, application of management tools and strategic point focus.

Table 2 - Comparative Overview: Apple vs. Microsoft GHG Protocol

Category	Apple	Microsoft
Primary business model influencing emissions	Consumer electronics & vertically integrated supply chain	Cloud computing, AI infrastructure, hardware & software ecosystems
Scope 1 emissions	Low, declining due to electrification & facility efficiency	143,510 mt CO ₂ e (FY 2024) - facilities, data centers, fleets
Scope 2 emissions	Near zero; 100% renewable electricity	259,090 mt CO ₂ e (market-based, FY 2024); increasing energy demand
Scope 3 emissions	Largest share but mitigated through supplier renewable energy (17.8 GW in 2024)	Dominant category: 15,140,000 mt CO ₂ e (FY 2024)
Key managerial accounting tools	Carbon budgets, supplier scorecards, lifecycle analysis	Internal carbon fee, scenario modeling, emissions-intensity dashboards
Verification & transparency	GHG Protocol aligned, detailed reporting	Independent audit (Deloitte), recalculation policy, high transparency
Strategic focus	Supply-chain renewable energy & low-carbon materials	Cloud decarbonization, renewable procurement, carbon removal
Main challenges	High Scope 3 from manufacturing partners	Extreme Scope 3 dominance, rapid growth of cloud & AI demand

Source: Authors based on Apple (2025) and Microsoft (2025)

While both companies maintain rigorous control over Scope 1 and Scope 2 emissions, Apple's early transition to 100% renewable electricity across its corporate operations enabled near-complete elimination of Scope 2 impacts. Microsoft has made similar progress but faces larger absolute energy

demand due to rapid expansion of cloud infrastructure, resulting in 259,090 mt CO₂e under Scope 2 (market-based) in FY 2024.

Both companies integrate carbon accounting into internal managerial decision-making, though the mechanisms differ in scale and scope. Apple

employs carbon budgets, supplier scorecards, and lifecycle assessments as part of its managerial accounting system, enabling emissions to be treated as performance-based indicators influencing procurement and design decisions. Microsoft goes a step further by implementing an internal carbon fee, charged to business units based on their emissions. This approach operationalizes CO₂ as a financial variable, embedding emission costs directly into budgeting and planning processes.

In Apple's case, emissions accounting primarily enhances supplier management and product lifecycle optimization. For Microsoft, managerial accounting tools are more tightly connected to financial planning, scenario modeling, and cloud infrastructure investment decisions.

Apple has achieved measurable reductions in emissions through aggressive interventions in supplier renewable energy adoption, materials recycling, and product energy efficiency. Its long-term strategy centers on lowering upstream manufacturing emissions and minimizing downstream usage impacts through energy-efficient device design.

Microsoft, although committed to becoming carbon-negative by 2030, faces structural constraints due to the exponential growth of artificial intelligence and cloud computing. These sectors inherently require significant energy inputs and generate extensive supply-chain emissions. As a result, Microsoft's Scope 3 emissions - 15.14 million mt CO₂e in FY 2024 - represent its largest strategic challenge. Both firms have transparent reporting systems aligned with the GHG Protocol, but Apple demonstrates more pronounced reductions in absolute terms, while Microsoft exhibits strong methodological rigor and financial integration of carbon metrics.

The comparative analysis highlights that while both companies demonstrate strong alignment with the GHG Protocol, their managerial accounting applications diverge due to differing operational structures:

- Apple's decarbonization success is driven by supply-chain transformation, making managerial accounting a tool for operational control and sustainability performance evaluation.
- Microsoft's approach positions CO₂ as a financialized variable, internalized through carbon pricing mechanisms and embedded in budgetary control, but its emissions are more difficult to reduce due to the nature of cloud infrastructure and value-chain dependencies.

Both cases demonstrate that managerial accounting systems - when combined with standardized carbon reporting frameworks - serve as powerful tools for identifying emission hotspots, guiding investment decisions, and integrating sustainability metrics into corporate governance.

These comparisons highlight the importance of incorporating carbon metrics into management decision-making to drive both operational improvements and strategic sustainability outcomes.

Qu et al. (2022) demonstrates the application of Material Flow Cost Accounting (MFCA) within budgeting by developing an MFCA-Activity-Based Budget (ABB) model for a liqueur manufacturing company in China. The model integrates not only operational costs but also environmental flows, such as resource use, waste, and emissions, into the budgeting process. By doing so, managerial decisions incorporate both financial and ecological components, enabling managers to plan resources while considering emissions and environmental impacts. This case highlights how managerial carbon accounting can be directly applied to budget planning, linking operational and environmental management for improved sustainability performance.

A Spanish winery implemented Material Flow Cost Accounting (MFCA) to monitor material flows and CO₂ emissions across the entire production process, from raw grapes to the final bottled product. This approach allowed the company to quantify the carbon footprint at each production stage, enabling precise tracking and management of emissions. The results demonstrated that integrating carbon accounting into managerial decision-making not only reduced environmental impacts but also generated significant financial benefits, including lower energy consumption, more efficient processes, and improved collaboration with suppliers. Moreover, the introduction of MFCA shifted the organizational culture, increasing employees' awareness of CO₂-related costs and fostering proactive involvement in sustainability initiatives. The winery also optimized its procurement strategy, selecting packaging with lower carbon emissions, thereby aligning operational decisions with environmental objectives. This case illustrates how managerial carbon accounting can serve as an effective tool for both environmental management and operational decision-making (Marco-Fondevila et al., 2020).

Gibassier and Schaltegger (2015) present an in-depth case study of a multinational company implementing managerial carbon accounting (MCA) to integrate both product-level and organizational-level emissions. The study highlights how MCA

enables internal managers to track and control CO₂ emissions, supporting informed decision-making for mitigation strategies. By combining different accounting approaches, the company improved the accuracy of emission data and enhanced internal communication regarding carbon performance. The case illustrates that managerial carbon accounting can serve not only as a measurement tool but also as a strategic instrument for guiding operational and investment decisions. Challenges such as varying data sources, emission factors, and system integration were addressed, demonstrating practical considerations for successful implementation. Overall, the study shows that MCA can bridge the gap between theoretical carbon accounting frameworks and real-world business practices, making it highly relevant for organizations seeking to reduce their carbon footprint effectively.

Deac (2013) examines three different accounting models employed by companies participating in an Emissions Trading Scheme (ETS): the cost model, the revaluation model, and the off-balance-sheet approach. The study demonstrates how the choice of accounting method impacts the balance sheet, income statement, and key financial indicators. While the focus is primarily on financial carbon accounting, the case highlights practical implications for decision-making and illustrates how accounting choices influence both reporting and internal management of emissions. This study is particularly relevant for understanding the distinction between financial carbon accounting (FCA) and managerial carbon accounting (MCA), showing that methodology affects not only compliance and external reporting but also internal strategy and resource allocation.

These case studies from literature confirm that managerial accounting effectively bridges operational and financial decision-making with environmental impact, providing practical guidance to organizations seeking to reduce their carbon footprint.

CONCLUSION

The findings of this research demonstrate that managerial accounting plays a pivotal role in modern corporate strategies aimed at controlling and reducing CO₂ emissions. The application of the Greenhouse Gas (GHG) Protocol, as a globally recognized standard for quantifying and categorizing emissions, enables companies to establish transparent, comparable, and reliable carbon data. However, the true strategic value of the GHG Protocol emerges only when emissions information is fully integrated into internal managerial accounting systems - particularly within planning, control,

budgeting, investment decision-making, and performance evaluation processes.

The case studies of Apple and Microsoft illustrate that organizations that systematically apply the GHG Protocol and embed carbon metrics into their managerial tools achieve greater accuracy in identifying emission sources and stronger effectiveness in implementing decarbonization strategies. Apple has achieved substantial progress through supply chain transformation, investments in renewable energy, and the incorporation of carbon indicators into product design and procurement processes. Microsoft, despite advanced reporting mechanisms and an internal carbon fee system, continues to face structural difficulties driven by the rapid expansion of energy-intensive cloud and AI infrastructure. These differences highlight that the success of emission-reduction initiatives depends largely on an organization's ability to align managerial focus with its dominant sources of carbon impact - whether in the supply chain, operational logistics, or downstream product use.

Overall, the analysis confirms that managerial accounting serves as a vital mechanism for operationalizing sustainability objectives. It enables CO₂ - treated as a quantified and financially relevant variable - to become an integral part of business decision-making, rather than a stand-alone environmental reporting requirement. The introduction of internal carbon budgets, carbon pricing mechanisms, emission-cost analyses, and the integration of carbon indicators into strategic planning empowers organizations to enhance efficiency, mitigate risks, and build long-term competitive advantages in an environment where decarbonization is becoming a core business imperative.

Accordingly, this study contributes to understanding how the GHG Protocol can function as a foundation for managerial accounting and demonstrates how different corporate structures and business models shape the opportunities and limitations associated with emission reduction. The empirical insights from the case studies suggest that future research should focus on developing advanced models of internal carbon cost allocation, evaluating the effectiveness of emission-reduction strategies across industries, and assessing the implications of digitalization and artificial intelligence on the evolution of corporate carbon footprints.

Acknowledgement

This paper is part of the research results on Project U 01/2023 Green economy in the era of digitization and Project U 01/2024 Sustainable development and environmental protection in economy, Faculty of Finance, Banking, and Auditing, Alfa BK University.

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