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Sustainable Innovation or Merely Reporting? State of the Art of Assessing Scope 3 Emissions of Organizational Procurement

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Abstract Amid growing regulatory pressure and sustainability goals, organizations face challenges in accurately assessing procurement-related carbon emissions. Scope 3 emissions from purchased goods and services are often calculated using either Life Cycle Assessment (LCA) or Environmentally Extended Input–Output (EEIO) analysis with spend-based data. While EEIO offers ease of use, it lacks the granularity needed for effective decarbonization. LCA provides precision but remains resource-intensive and limited by data availability. Through a systematic literature review, this study analyzes 54 case studies to assess the suitability of these methods and their alignment with decarbonization strategies. Results reveal a disconnection between stated goals and chosen methodologies, with many organizations relying on imprecise data despite ambitious targets. Hybrid approaches emerge as a pragmatic compromise, combining scope with feasibility. This contribution invites a shift beyond basic reporting toward harmonized, reliable methods that enable actionable sustainability strategies.

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1 Introduction

Organizations face growing pressure to reduce their environmental footprint, with an increasing focus on indirect emissions from activities in the up- or downstream value chain classified as Scope 3 under the Greenhouse Gas Protocol (WRI and WBCSD 2011). These emissions, particularly from purchased goods and services, often represent around 75% of a company's total carbon footprint across sectors but occur outside of the organization's control. The share of Scope 3 emissions differs depending on the sector, with manufacturing organizations having higher Scope 3 emissions than service-oriented organizations (Alvarez et al. 2014; Blanco et al. 2016). Accurately quantifying procurement-related emissions is thus essential for effective climate strategies.

Regulatory initiatives, such as the European Union's Corporate Sustainability Reporting Directive (CSRD), now require Scope 3 emissions disclosure as a part of broader sustainability reporting (European Commission 2023). However, wide variations in quantification methods complicate comparability and decision-making (Baehr et al. 2024). Common approaches include Life Cycle Assessment (LCA), which provides product-level insights but is resource-intensive (Sonnemann and Margni 2016), and Environmentally Extended Input–Output (EEIO) analysis, which offers broader system coverage but often lacks granularity (Suh 2009).

To address these trade-offs, hybrid methods combining LCA and EEIO or integrating monetary and physical data have emerged as practical solutions (Cimprich and Young 2023; Finogenova et al. 2019). Yet, terminology inconsistencies, misaligned system boundaries, and varying inventory approaches and impact assessment methods remain widespread. As a result, many assessments fall short of supporting meaningful decarbonization, instead of serving primarily as compliance or reporting functions (SBTi 2024).

This paper applies the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework (Page et al. 2021) to examine 54 case studies on procurement-related carbon accounting. It analyzes methodological choices, data sources, and goals of each study, evaluating their alignment with effective sustainability strategies. To guide this review, the following research questions are posed:

RQ1: What carbon accounting methodologies are most applied to assess procurement emissions in the scientific literature, and what are their main strengths and limitations?

RQ2: What inconsistencies can be observed across standards and methodologies, and how do these affect the reliability of procurement emission assessments?

RQ3: How well are the employed methods aligned with the stated sustainability goals of the studies, and how suitable are they for supporting actionable decarbonization strategies?

By addressing these questions, this study supports efforts to harmonize procurement emissions accounting as there is, to the best of our knowledge, no comprehensive review regarding procurement emission calculations. This work seeks to support a shift from emission reporting to impact-driven actions.

2 Methodology

This review adheres to the PRISMA framework (Page et al. 2021) through a seven-step protocol to locate, screen, and analyze peer-reviewed studies on procurement-related Scope 3 carbon accounting.

Step 1: Web of Science and Scopus were queried in May 2024 using keywords and synonyms related to "organizational LCA," "EEIO," "carbon accounting," "Scope 3," "procurement," and "supply chain" while no regional limitations were defined, yielding 384 articles published between the years 2009 and 2024; Step 2: Duplicates, non-English or non-peer-reviewed articles were removed; Step 3: Papers not addressing carbon accounting or procurement and reviews were removed; Steps 4—5 entailed a full-text screening. Only articles with explicit methodological detail on procurement-focused carbon accounting were included; Step 6: A backward search in Google Scholar added further relevant case studies; Step 7: The final pool consisted of 44 articles covering 54 case studies.

The methodological analysis entails the categorization of carbon accounting methods as well as data and inventory approaches. In the application analysis, goal alignment, standards, system boundaries, and data sources are analyzed in accordance with the LCA standard. The structured review matrix is provided as supporting material.

3 Results

This section presents the key findings from the 54 selected studies on methods, data, inventories, and the standards used to assess procurement-related carbon emissions.

3.1 Inventory Approaches and Emission Quantification Methods

Procurement emission assessments in the reviewed case studies rely on three main inventory approaches: top-down, bottom-up, and hybrid. In top-down inventories, activity data are collected at the organizational level from aggregated sources such as procurement or accounting systems, utility bills, or fuel records, without allocation to specific products or activities. This approach is well suited to EEIO analysis, which matches monetary spend data with sector-based emission factors to provide economy-wide coverage. While EEIO is a common top-down method, not all top-down approaches rely on monetary data; physical data sources are also widely used. In fact, 34% of top-down studies in our review employed physical activity data. In contrast, bottom-up inventories use physical data, such as weight, volume, or quantity of products purchased, to assess emissions at a more granular level. This approach is usually adopted in LCA-based models and allows for more detailed hotspot analysis and product-level interventions. However, it often requires intensive data collection efforts and is limited by data availability across diverse procurement portfolios (Rimano et al. 2021; Toniolo et al. 2023).

Although, the term hybrid is used variably across studies and can refer to: (1) combining LCA and EEIO models in a single assessment (Finogenova et al. 2019); (2) merging supplier-specific Scope 1 and 2 data with generic upstream emission factors (Aigner 2024; WRI & WBCSD 2011); (3) integrating top-down and bottom-up inventory structures (UNEP 2015); or (4) blending monetary and physical activity data to improve completeness (de Camargo et al. 2019). This diversity highlights the need to clarify what hybridization entails in each context.

Hybrid inventory approaches aim to overcome the limitations of top-down and bottom-up methods by combining their strengths. For example, organizations may apply a top-down model for broad procurement and a bottom-up model for high-impact purchases. Nine case studies adopted such hybrid structures, sometimes integrating different data types to improve accuracy (Finogenova et al. 2019).

Regarding emission quantification, LCA was used in 46.3% of studies, offering robust, product-level insights suitable for supplier engagement and eco-design (Cucchi et al. 2023). However, its application was often limited by data availability and complexity. EEIO, used in 22.2% of cases, enabled broad system coverage and ease of use through national or global input–output tables (Kjaer et al. 2015; Suh 2009), but lacked granularity. Hybrid methods, adopted in 20.4% of the studies, sought to balance detail and scalability by integrating LCA and EEIO methods (Finogenova et al. 2019). Figure 1 illustrates how different inventory structures, data types, and accounting methods interact within an organizational context.

These variations reveal the fragmentation in hybrid modeling practices. Although hybridization helps address the limitations of LCA and EEIO, the absence of clear definitions and guidelines hinders comparability and replication. This highlights the need for standardized frameworks and harmonized reporting to improve transparency and support decision-making in carbon accounting.

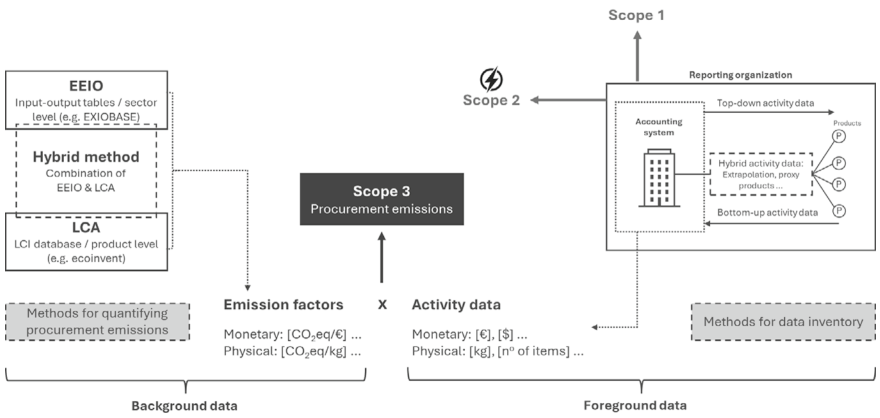

Fig. 1 Sketch of methods for data inventory and procurement emissions quantification

3.2 Carbon Accounting Practices in Case Studies

3.2.1 Classification and Analysis of Case Study Goals

Every study should be guided by a clear goal and scope definition and employ appropriate methods to meet its goals (UNEP 2015). To compare these goals, we used deductive analysis to group individual goals into 11 generic categories defined by the OLCA standard. Most studies pursued multiple goals, though prioritization was unfeasible due to inconsistent descriptions. While 57% focused solely on carbon emissions, the rest applied multi-criteria approaches across impact categories. OLCA categorizes goals as analytical (e.g., quantifying hotspots and reduction opportunities), managerial (e.g., informing procedures, reporting, and marketing), or societal (influencing external stakeholders). The most common goals, hotspot identification, strategic decision support, and impact reduction, spanned all three categories. Related goals include risk assessment, procedure improvement, and performance tracking. Less frequently cited were cost reduction, marketing, supply chain management, and stakeholder motivation (UNEP 2015).

3.2.2 Carbon Accounting Standards and System Boundary Definitions

The use of internationally recognized standards varied considerably across the reviewed case studies. Out of the 54 analyzed cases, 16 explicitly adopted the Organizational Life Cycle Assessment (OLCA) framework (UNEP 2015), 8 referred to the GHG Protocol Standard (WRI and WBCSD 2011), and 3 applied the European Commission's Organizational Environmental Footprint method. These frameworks provide structured guidance on system boundaries, data quality, allocation procedures, and reporting formats.

However, over one-third of the studies did not mention any standard explicitly, and several others only cited them without demonstrating operational integration into their accounting practices. This lack of formal adherence raises concerns about the transparency, especially for studies aimed at informing organizational decisions or supporting regulatory compliance (Baehr et al. 2024).

Differences were also observed in the interpretation of system boundaries. Some studies limited their scope to Tier 1 upstream suppliers, while others applied cradle-to-gate or cradle-to-grave perspectives, sometimes without clearly specifying the cut-off criteria. These inconsistencies further highlight the need for clearer methodological documentation and standardized reporting.

3.2.3 Foreground Data and the Role of Accounting Systems

The assessment of procurement-related emissions begins with collecting foreground data, flows directly controlled or recorded by the organization, such as purchases, quantities, or specifications, and are essential for linking procurement actions to environmental impacts. Their availability, quality, and structure strongly influence method selection and results accuracy (Essouid et al. 2026).

Across the reviewed case studies, limited data availability was a major constraint for applying the bottom-up approach. As a result, most organizations use multiple internal and external data sources, often varying in granularity and format, which created integration challenges and affected assessment robustness (Cucchi et al. 2023).

Accounting and procurement records (e.g., invoices, purchase orders, and stock inventories) were the most commonly used foreground sources, observed in approximately one-third of the cases. These records supported both monetary and physical data types (Fig. 1). Other sources included internal documents (e.g., technical sheets), supplier data, surveys, literature proxies, and on-site measurements. Enterprise systems such as ERP and MRP often helped consolidate procurement data and support automated classification across multiple sites. Yet, data silos between environmental and procurement systems limited Scope 3 resolution and detailed modeling.

In summary, foreground data availability and data types, especially from accounting systems, shaped methodological choices. These findings highlight the strategic role of digital procurement infrastructures and the integration of environmental data into purchasing workflows to enable scalable and reliable carbon accounting.

3.2.4 Emission Factors and Background Data Sources

Background data represent upstream processes and emissions outside the organization's direct control and are essential for quantifying embedded impacts across the supply chain. Typically sourced from standardized environmental databases, they are used to assign emission factors especially when supplier-specific data are unavailable. Two main types of emission factors (Fig. 1) were identified in the reviewed studies: monetary emission factors (e.g., kg CO_2eq/€) or physical emission factors (e.g., kg CO_2eq/quantity (i.e., kg, kWh, L…)).

Monetary emission factors, commonly used in top-down and EEIO-based approaches, were derived from databases such as EXIOBASE, USEEIO, and CEDA. These provide wide coverage by linking economic flows with environmental extensions, but rely on sector averages that may not reflect the product- or supplier-specific emissions (Suh 2009). Their accuracy depends on database granularity (e.g., EXIOBASE provides EU country-specific data, while USEEIO is U.S.-focused), affecting interpretability and reliability of results (Keil 2023; Kjaer et al. 2015).

Physical emission factors, mostly used in bottom-up models, were sourced from LCI databases like ecoinvent or GaBi. They enable detailed modeling linked to specific materials and processes (Cucchi et al. 2023), and are better suited for high-impact purchases. However, they require precise foreground data and involve greater modeling effort, limiting their use in broad organizational assessments. Several hybrid studies combined supplier-specific or process-level data (e.g., energy use, transport distances) with background emission factors from standardized databases to enhance specificity. However, many lacked documentation on database versioning, system boundaries, allocation rules, and regional matching (Finogenova et al. 2019).

Overall, while background data are essential, the studies revealed inconsistencies in selection, reporting, and integration. Assumptions about data age, region, and representativeness were often missing, hindering comparability and interpretation.

These findings underscore the need for transparent reporting, alignment between foreground and background data, and standardized criteria for database selection. Developing region- and industry-specific datasets, for both monetary and physical emission factors, is the key to improving accuracy and relevance in procurement carbon accounting.

3.2.5 Impact Assessment Methods

The selection of impact assessment methods is critical for interpreting environmental results; however, reporting varied widely across the reviewed studies. Only about half of the cases using physical data (typically in LCA or hybrid models) clearly specified the impact assessment method applied; others omitted or partially reported this information. In contrast, studies based solely on monetary data (e.g., EEIO) often inherited predefined methods from the databases used, limiting transparency and methodological control. The IPCC Global Warming Potential was the most frequently used method (32%), particularly for mono-criteria assessments, together with ReCiPe. Other common methods included CML (15%), TRACI (5%), EF (5%), and IMPACT 2002 + (5%), though these were cited less frequently. Although method choice was sometimes category-specific, methodological justification was rarely discussed, underscoring the need for more consistent and transparent impact method selection.

4 Discussion

This review synthesizes methods for quantifying Scope 3 procurement emissions, highlighting key inconsistencies and trade-offs across 54 studies and proposing a framework for methodological harmonization.

4.1 Inconsistencies in Procurement Emission Calculations

Significant inconsistencies were observed across the reviewed case studies, affecting data quality and transparency. Many did not clearly document system boundaries, inventory structure, impact assessment methods, or emission factor sources. Some procurement categories were excluded without justification, particularly in GHG Protocol-based approaches. Variability also arose from differing treatments of monetary data (e.g., basic prices versus purchase) and inconsistent classification of purchased electricity (e.g., Scope 2 versus Scope 3).

Foreground data gaps were common. Limited access to supplier-specific data led to reliance on secondary sources or assumptions. Emission factors ranged from broad EEIO averages to product-specific LCA values, contributing to inconsistent results. Methodologies varied significantly: EEIO offered coverage but lacked granularity; LCA was precise but data-intensive; hybrid methods aimed to balance the two but often lacked integration clarity (Finogenova et al. 2019; Kjaer et al. 2015; Suh 2009). Use of outdated factors and missing uncertainty assessments further weakened robustness.

Differences in standard interpretation also played a role. "Hybrid" was defined inconsistently, ranging from mixed data types to combined inventory structures. OLCA emphasized cradle-to-gate or cradle-to-grave flows, while GHG Protocol studies often used activity-based groupings with limited product-level detail. These divergences complicated benchmarking, particularly in the service sector where downstream impacts are frequently excluded.

4.2 Methodological Trade-Offs and Goal Alignment

A key insight from the reviewed case studies is the frequent mismatch between the goals stated by organizations (e.g., hotspot identification, supplier engagement, or emissions reduction) and the data or methods actually used. Although many studies pursued ambitious decarbonization objectives, they often relied on top-down monetary data, which lacks the resolution necessary for actionable insights. Conversely, bottom-up physical data, better suited for process-level interventions, was underused due to demanding data requirements. Hybrid inventories that combined data types offered a practical balance but were inconsistently applied and often under-documented. As shown in Fig. 2, studies frequently used top-down monetary data even for detailed goals, while more appropriate bottom-up or hybrid approaches were applied less systematically. Overall, methodological choices appeared more influenced by data availability than by alignment with stated sustainability objectives.

4.3 Pathways for Harmonization

To enhance consistency and strategic relevance in procurement carbon accounting, a harmonized framework is needed. Figure 3 proposes a structured integration of organizational and product-level perspectives, adapted from Aigner (2024). It distinguishes between three categories of emissions: core activities (direct product-related operations), supporting activities (indirect but attributable emissions such as packaging or logistics), and overhead activities (non-product-specific emissions like employee commuting or investments). Core and supporting activities are typically product-related and offer direct mitigation potential through emission assessments with physical data or bottom-up inventories. Overhead activities are less controllable and primarily relevant for transparency and screening purposes, where less accurate top-down and monetary emission calculations suffice. This structured differentiation helps organizations identify active emissions that are manageable and reducible, as opposed to those that are passively disclosed. It also facilitates better integration of environmental and procurement systems, supports clearer data governance, and aligns reporting structures with operational realities. By promoting a shared logic between Scope 3 activity categories and product-oriented emission flows, this approach advances the strategic use of carbon data, shifting procurement accounting from a compliance tool to a platform for decarbonization action.

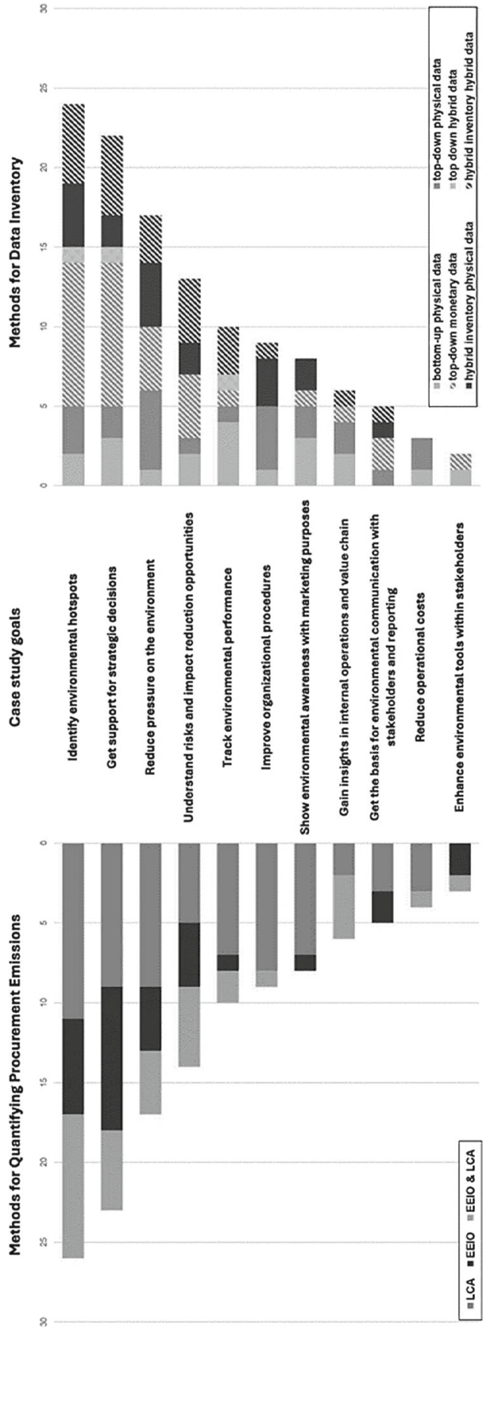

Fig. 2 Alignment of goals, inventories, and emission quantification methods

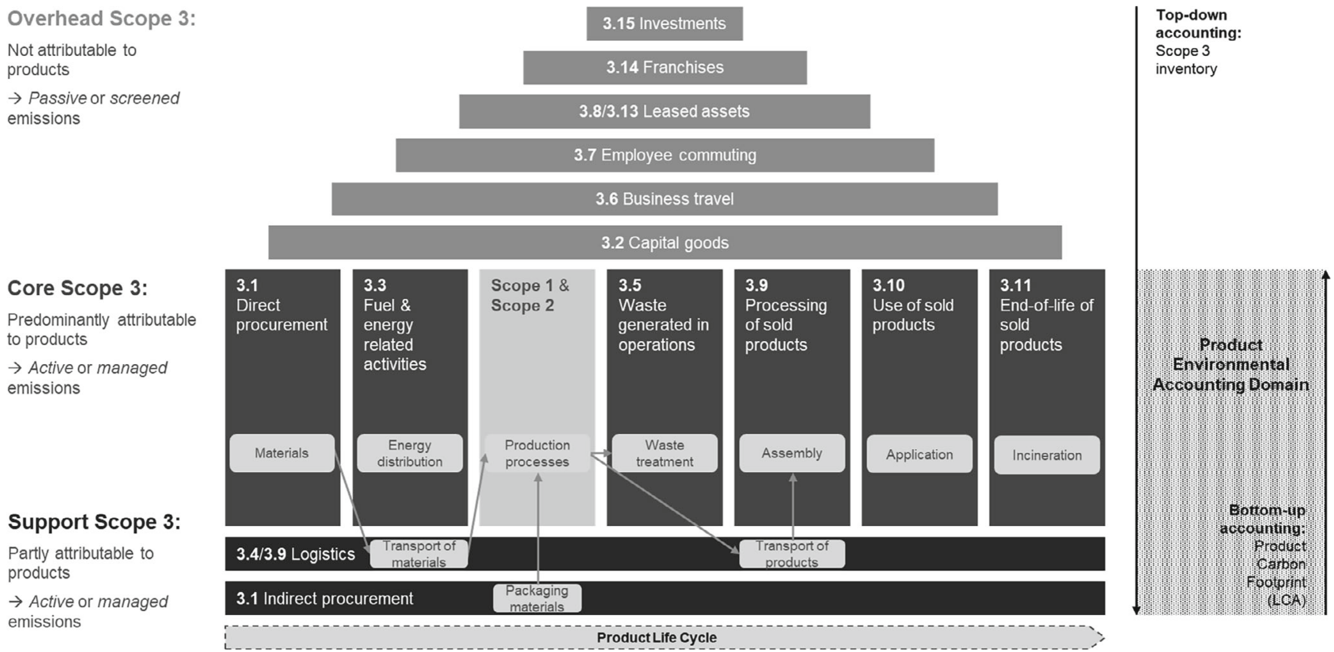

Fig. 3 Alignment of organizational and product-based accounting (Adapted from Aigner 2024)

5 Conclusion

This review examined current methodologies for accounting Scope 3 procurement emissions, with a focus on LCA, EEIO, and hybrid approaches. LCA provides detailed, product-level insights but is often constrained by data availability and modeling complexity. EEIO methods offer broader system-level coverage and scalability but lack the granularity needed for supplier- or product-specific decision-making. Hybrid approaches attempt to balance these trade-offs by integrating monetary and physical data or combining top-down and bottom-up inventories. However, their application remains inconsistent, and their effectiveness in supporting decarbonization efforts is not yet well demonstrated.

The findings highlight persistent challenges related to supplier data availability, reliance on generic emission factors, and limited transparency in methodological choices. Many studies showed a misalignment between their goals and the methods applied, often driven more by data availability than by strategic intent. Integrating economic performance metrics, such as Life Cycle Costing (LCC), could enhance the decision-making potential of procurement carbon accounting. Geographic and sectoral representation in the literature remains uneven, limiting the generalizability of current insights. Existing standards, including the GHG Protocol, should be re-evaluated in light of methodological developments and contextual needs.

To improve accuracy and impact, future efforts should focus on enhancing data quality, promoting open-access databases, and leveraging technologies such as AI and real-time monitoring. Harmonizing standards and encouraging organizational engagement beyond reporting will be key to unlocking the full potential of Scope 3 carbon accounting as a strategic sustainability tool.

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