Environmental and Carbon Costing Systems: A Systematic Review of Green Cost Accounting Practices

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DOI: https://doi.org/10.47772/IJRISS.2026.10200527

Received: 23 February 2026; Accepted: 28 February 2026; Published: 18 March 2026

ABSTRACT

This systematic review focuses on the history of environmental and carbon costing systems, its application, and development of the methodology in the industries and international environment. The review is a synthesis of evidence by key frameworks of Environmental Management Accounting (EMA), Material Flow Cost Accounting (MFCA), Full Cost Accounting (FCA), carbon foot printing methods, and internal carbon pricing mechanisms. It has been found that these costing systems are very important in enhancing cost visibility, waste streams, resource efficiency, and corporate sustainability strategies. MFCA and EMA continue to represent the most common form of implementation, especially in manufacturing and high impact industries whereas carbon accounting and pricing instruments become even more popular in support of making investment decisions and estimating climate risks. Although they have potential, adoption is not even because not all are measured, standard guidelines are not used, data quality is not always good, especially with Scope 3 emissions, and is not well integrated with financial reporting. There is also a lack of longitudinal studies, and SMEs and developing economies are underrepresented using empirical evidence. The review also indicates an increasing interest in digitalization, such as AI monitoring and real time emission tracking, but they are not in practical use. The improvement of methodological consistency and the broader and more extensive research in a variety of industry and other geographic settings will help to develop green cost accounting and aid low carbon decision making.

Keywords: Environmental Costing, Material Flow Cost Accounting, Carbon Accounting, Environmental Management Accounting, Internal Carbon Pricing.

INTRODUCTION

Increasing environmental pressures, carbon emission and high global sustainability obligations have heightened concern over cost accounting systems to capture environmental and carbon-related impacts. The traditional cost accounting usually disregards or under values the environmental externalities of pollution, loss of resources and carbon emission. Consequently, companies can make choices that seem economically effective, but which are hazardous to the environment. The last 20 years had seen the rise in the significance of environmental costing and carbon costing systems as companies have been subject to increasingly tough regulatory policies, carbon pricing systems, and ESG reporting. Green cost accounting can offer the means of identifying, quantifying, and assigning environmental and carbon costs to products, processes, or organisational operations, to support more precise financial decision-making and sustainable actions. Despite the increased development of this field, practises are still disjointed and heterogeneous in industries and geographic settings. The various methods available, i.e. Environmental Management Accounting (EMA), Material Flow Cost Accounting (MFCA), Full Cost Accounting (FCA), and carbon foot printing, provide different methods, scopes and different levels of detail. Nevertheless, the standard of environmental or carbon costing does not exist, and it poses difficulties with comparability and incorporation into standard accounting and finance. Considering the growing importance of the sustainability aspect in corporate governance and the expectations of the investors, the systematic review is required to summarise the existing knowledge, outline methodological drawbacks, and suggest the opportunities to continue the investigation in this dynamic field. The objective of this review is to trace the application of environmental and carbon costing systems, evaluate their effects on the performance and firm decision-making processes, and suggest future development trends of green cost accounting practises.

Conceptual Background

Environmental Accounting

Environmental accounting is an extension of traditional accounting which incorporates environmental effects onto financial analysis including resource use, waste levels, and environmental pollution. It improves decision-making as it helps organisations to internalise externalities as it tracks the environmental costs that are usually hidden in the traditional financial reports. This method facilitates sustainability because it would give a better understanding of the actual cost incurred on environmental degradation and resource consumption hence making businesses to be more responsible. Environmental accounting systems such as Environmental Management Accounting (EMA) and carbon management accounting can be used to measure these impacts both in terms of physical and monetary costs, which is more accurate than the traditional cost accounting techniques. Disclosing the environmental costs in addition to the financial information will help the firms to better allocate funds, abide by the regulations and make their operations in the context of sustainability. Overall, the environmental accounting is an important instrument to integrate the ecological factors into the corporate financial systems and strategies (Tsai et al., 2012; Goenka et al., 2025; Nyakuwanika and Panicker, 2025).

Environmental Costing Systems

Various environmental costing models have been devised to bring in environmental impacts in making financial decisions. Environmental Management Accounting (EMA) is an integration of physical and monetary information of the environment to trace material flows, waste, and emissions to make more informed decisions on environmental performance. Material Flow Cost Accounting (MFCA) is aimed at the measurement of material losses and the transformation into monetary expenses and assists organisations to determine inefficiencies and minimise waste. Full Cost Accounting (FCA) is an all-encompassing method as it encompasses direct, indirect, and outside environmental expenses when conducting financial analyses, which helps in gaining an impartial perspective of the effects of an organisation on the environment. These frameworks enable the allocation of resources in a better way as well as sustainability strategies as they unveil the hidden environmental costs to the traditional accounting systems. Although not similar, all of these approaches promote the adoption of environmental aspects in economic assessment and facilitate sustainable business behaviour (Asuzu et al., 2024; Ortiz-Cea et al., 2025; Rodrigues and Da Silva, 2024).

Carbon Costing Approaches

Carbon costing methods are aimed at measuring the quantity of greenhouse gas (GHG) emissions and the financial implications to aid the climate action and policy. Carbon foot printing quantifies all GHG emissions of products, processes or organisations and this forms a starting point of determining possible reduction points. Internal carbon pricing gives a financial purpose to carbon emissions inside the firms to motivate the reduction of emission and to direct investment choices. Carbon taxes and emission trading systems facilitate market-related systems that impose a price on carbon, which makes firms reduce carbon emissions via economic strategies. It is necessary to calculate Scope 1 (direct) and Scope 2 (indirect through purchased energy) and Scope 3 (other indirect) emissions to report fully and allocate costs but there are still problems regarding transparency and accuracy of these measurements. Better carbon emission monitoring and better accounting standards are expected to make the carbon data more reliable to improve the quality of decision-making and regulatory adherence (Liu et al., 2022; Glenk, 2025; Li et al., 2024; Miller et al., 2022).

Integration with Accounting and Finance

Environmental and carbon costing systems can help to improve financial decision making by providing a more precise allocation of costs based on the environmental impact, which will allow more effectively detecting inefficiencies and waste. These systems enhance the appraisal of investments by integrating environmental costs and the price of carbon, which assists companies to determine the economic feasibility of sustainability projects and retrofit projects with a positive economic contribution. They also facilitate the improved sustainability plans and risk management through incorporation of dynamic carbon price situations and regulatory variables in the financial models which enables the organisations to predict policy changes and market changes. The operation

of sophisticated solutions like the AI-based green costing in the enterprise resource planning systems further contribute to the incorporation of real-time data to make more intelligent and sustainability-conscious decisions. Empirical studies demonstrate that organisations that have high environmental and carbon performance have better financial performance due to higher operational efficiency and reputation, which has implied the strategic importance of these integrated strategies. In general, the integration of the expenses of the environment and carbon in the accounting system helps to create a broader perspective that is focused on profitability and long-term sustainability targets (Liu et al., 2025; Lin and Xu, 2025; Sanakal, 2025; Amalia and Aji, 2025; Nyakuwanika and Panicker, 2025).

METHODOLOGY (PRISMA-BASED SYSTEMATIC REVIEW)

Review Protocol

The research paper is based on the PRISMA 2020, which contains the updated and comprehensive recommendations to stick to the standards of transparency, completeness, and reproducibility of any systematic review report. The protocol used in the review was the clear definition of research questions, followed by systematic search of the databases of relevance and systematic screening of studies with the use of a set of inclusion and exclusion criteria. The process of data extraction involved administration of standardised forms to measure the most significant information of qualified studies and synthesise its results based on the 27-item checklist and flow chart of PRISMA. These areas assist in reducing bias and enhancing transparency of reporting by explaining how the review was done, the process of selecting the studies and what they discovered. The update of PRISMA 2020 identifies some improvements in the methodology and terminology that have been made since the original statement, 2009 version, with a greater focus on the identification, selection, appraisal, and synthesis of evidence. The compliance with this protocol helps conduct a strict assessment of the quality of evidence and emphasise the possibility of repeating or updating the review in the future (Page et al., 2020). The identification phase provided 1,930 records obtained in the review in major academic databases. The highest contribution was made by Scopus which offered 620 records as compared to Web of Science which offered 540 records and this is because they cover much high-quality peer reviewed research. The ScienceDirect had provided 460 records, mostly of Elsevier and its extensive environmental and sustainability journals, whereas Emerald Insight had provided 220 records, mostly of management and accounting journals. To have a thorough coverage and not to miss any other studies of interest, 90 records were located using Google Scholar and other supplementary databases, which facilitated the retrieval of grey literature and articles that are not included in the major databases. All these sources yielded a strong pre-duplication sample of 1,930 records that served as the basis of the further screening and eligibility evaluation steps.

A) Identification (by source)

Source	**Records identified (n)**
Scopus	620
Web of Science	540
ScienceDirect	460
Emerald Insight	220
Additional (Google Scholar/other)	90
Total before duplicates	**1,930**

In the screening stage, the first set of records (1,930) was cleaned with a deduplication option, where 530 of the records were deleted and the remainder was left with 1,400 unique records to view. Title and abstract screening were then done on these records where it was determined whether they were relevant to the environmental and carbon costing systems. Of the 1,400 items screened, 1,220 were rejected due to not meeting the predefined

inclusion criteria, which included but was not limited to not having a costing component, not being covered in the scope of either environmental or carbon accounting or having too little methodological information. Such a strict filtering meant that only studies that had a definite relevance and a methodical appropriateness carried on to the eligibility phase of full text evaluation.

B) Screening → Eligibility → Included

PRISMA stage	Item	n
Deduplication	Duplicates removed	**530**
	Records after duplicates removed	**1,400**
Screening	Records screened (title/abstract)	1,400
	Records excluded	1,220
Eligibility	Reports sought for retrieval	180
	Reports not retrieved	10
	Reports assessed for eligibility (full text)	170
	Full-text reports excluded (with reasons)	147
Included	**Studies included in the review**	**23**

PRISMA 2020 structure aligned with your methods section.

On the level of full text eligibility 147 studies were excluded based on definite methodological and relevance criteria. The most significant sample of 82 studies was filtered out as it was out of scopes, and it had no direct input to environmental or carbon costing, although they seemed to be relevant at first screening. Forty-one other studies have been excluded since they never mentioned any explicit costing method, which makes them inappropriate in a systematic review devoted to costing frameworks. Another 24 articles were excluded because they were not in English or their methodology was not detailed enough to extract and compare their results. These restrictions were necessary to guarantee that only the studies that featured rigorous, relevant and clearly defined costing methods were incorporated in the final synthesis to maintain the quality of the methodology of the review.

C) Full-text exclusion reasons (example breakdown)

Reason for exclusion	n
Out of scope / unrelated to environmental or carbon costing	82
No explicit costing method reported	41
Not in English / insufficient methodological detail	24
Total full-text exclusions	**147**

Databases Used

This systematic review paper utilised the following databases: Scopus, Web of Science, ScienceDirect and Emerald Insight because these databases were chosen since each of them has a wide range of multidisciplinary

academic works and is effective in indexing citations. Scopus and Web of Science are the most popular bibliographic databases with comprehensive coverage of journals and citation analysis facilities, which are essential in conducting strict literature search (Harzing and Alakangas, 2015; Zhu and Liu, 2020; Pranckute, 2021). ScienceDirect offers a great number of scientific articles, mainly published by Elsevier in different disciplines. Emerald Insight brings in specialised resources especially in business and management spheres. The search in Google Scholar has also been performed to find the grey literature and sources that were not included in the primary databases as well because it provides the most extensive coverage comprising theses, conference papers, and non-English resources (Gusenbauer, 2024; Falagas et al., 2007; Martín-Martin et al., 2018). A combination of these databases warrants a comprehensive and equal retrieval of pertinent studies in fields.

Search Strategy

Sample search string:

("environmental costing" OR "green cost accounting" OR "environmental management accounting"

OR "carbon costing" OR "material flow cost accounting" OR "internal carbon price")

AND ("firm*" OR "corporate" OR "financial performance" OR "decision-making")

Inclusion Criteria

The inclusion criteria of the review included peer-reviewed journal articles that address costing systems that deal with either the environmental, carbon, or sustainability. The inclusion criteria were that the studies needed to be of an empirical, theoretical, or conceptual nature where one of the aspects was discussed in relation to environmental or carbon costing methods. The criteria were used to select the research that will help to comprehend and develop sustainability-oriented costing practises in various industries and situations. This strategy provides a wide range of applicable literature on the subject, both in practise and theory of environmental cost accounting. Research was needed that would give a clue on the ways costing systems incorporated environmental or carbon consideration to foster decision-making and performance analysis. They are used to guide the in-depth analysis of the role and formation of the costing system systems related to sustainability in scholarly studies (Liu et al., 2025; Luo et al., 2020; Ortiz-Cea et al., 2025; Adebayo and Samuel, 2025).

Exclusion Criteria

To avoid accessibility and uniformity in language, the exclusion criteria of the study were non-English publications. Articles that had not directly covered the aspects of costing mechanisms were sifted out in favour of those that were relevant. Also, abstracts of the conferences without a complete methodology section were excluded to make sure that all detailed and rigorously described studies would be included. These criteria were meant to make the literature chosen more qualitative and relevant by emphasising on fully established research with definite costing frameworks. This methodology is useful in preventing partial or unclear data that will invalidate the analysis of costing mechanisms. This is typical of systematic reviews to maintain methodological rigour and clarity (Špacírová et al., 2020; Burgess et al., 2020; Marques and Alves, 2023).

Data Extraction Fields

The following table represents data extraction fields in form of a table with approximate 23 studies on costing methods and methodologies:

Author and Year	Industry/Country Context	Costing Method Used	Methodology	Key Findings	Limitations
ISO (2011)	Cross-industry, global	Material Flow Cost Accounting	International standard/framework defining objectives,	Provides common terminology and a stepwise approach to trace material flows and assign	Does not prescribe detailed calculation

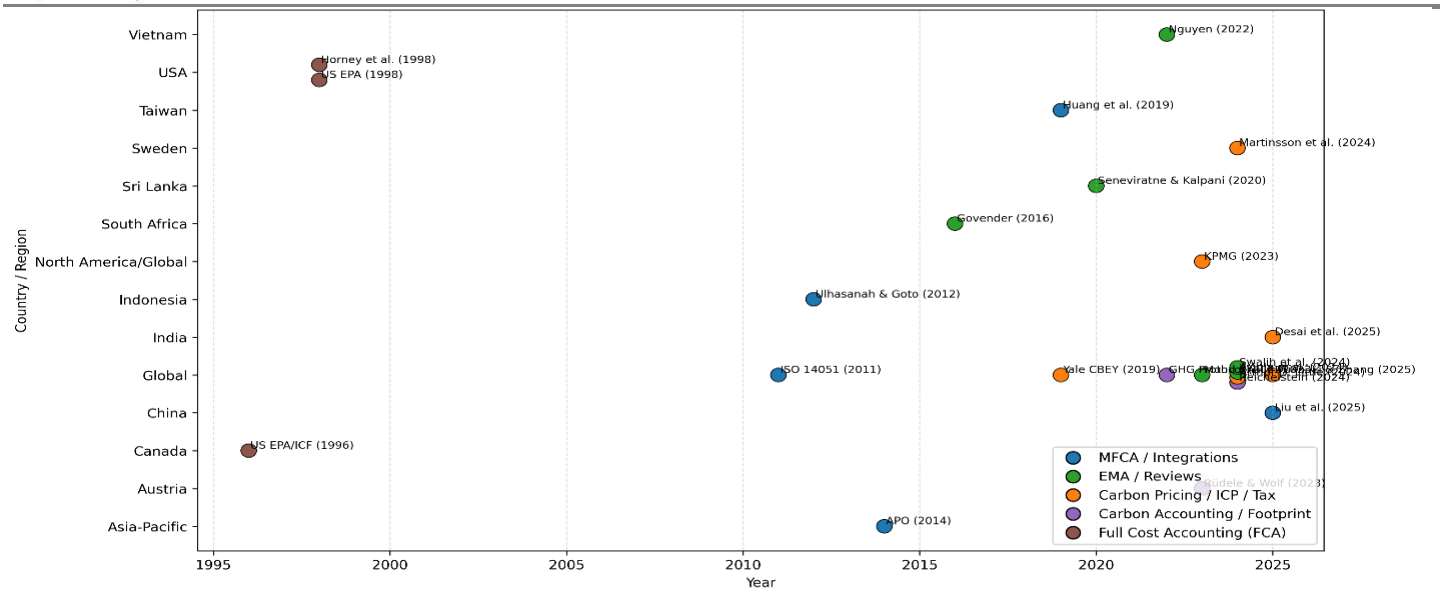
		(MFCA) — ISO 14051	elements, implementation steps	costs for internal decision-making	procedures; external costs outside scope
APO (2014)	Asia-Pacific, manufacturing case included	MFCA (ISO 14051)	Practical manual with modules and a case study for waste reduction	MFCA increases transparency of material flows and supports waste minimization with financial benefits	Guidance-oriented; limited generalizable empirical evidence
Huang et al. (2019)	Electronics supplier, Taiwan	MFCA (ISO 14051-based)	Single firm case study analyzing recycled glass reuse	MFCA revealed higher costs in recycled glass reprocessing than expected, informing process decisions	Single case; sector-specific constraints
Puspita et al. (2025)	MDF-based coffin manufacturing, Indonesia	EMA with MEFA/ECA aligned to MFCA	Single case study with interviews, observations, measurements	Identified raw materials as dominant cost; 16.1% cost absorption from solid waste highlighting savings potential	Context-specific; short-term focus
Seneviratne & Kalpani (2020)	Manufacturing, Sri Lanka	Environmental Management Accounting (EMA)	Qualitative case study using interviews, observations, documents	Stakeholder pressures (coercive/mimetic/normative) drove EMA and waste management practices	Single company; potential researcher bias
Nguyen (2022)	Pulp & paper, Vietnam	EMA adoption factors	Survey of 290 firms; statistical analysis	Identified organizational and regulatory drivers influencing EMA implementation	Sector-specific; self-reported survey data
Mohd Khalid (2023)	Multi-industry, global (2015–2020)	EMA tools incl. MFCA	Systematic review of 72 articles	MFCA most recorded tool; drivers/barriers mapped across industries	Review limited to English and 2015–2020 window
Govender (2016)	Manufacturing, South Africa	EMA (physical & monetary)	Firm-level survey/case within one organization	Positive EMA practice; better direct allocation of environmental costs to products	Single-organization scope
Desjardins & Sinclair-Desgagné (2025)	Multidivisional firms, theoretical	Internal Carbon Pricing (ICP)	Analytical model of transfer pricing with carbon fares	Internal carbon prices can transmit external carbon costs across divisions influencing production and abatement	Theoretical; lacks empirical validation
Yale CBEY (2019)	Universities & corporates (Microsoft, Société	ICP (internal carbon charge)	Policy framework +	ICP guides investment decisions and funds decarbonization; diverse	Case-based; non-random selection

	Générale, airlines)		multiple case studies	design choices documented	
Desai et al. (2025)	Listed firms, India (emerging market)	Carbon management incl. ICP	Panel regressions (2014–2023); moderation tests	Higher emissions reduce firm value; carbon management practices moderate the negative effect	Emerging market focus; generalizability limits
KPMG (2023)	North America & global corporates	Internal Carbon Pricing	Practitioner whitepaper with survey stats and case	ICP helps manage transition risk and fund renewables; adoption growing but data complexity is a barrier	Non-peer-reviewed; descriptive
Arthur D. Little (2024)	Global corporates	ICP across Scope 1–3	Consulting report with framework and examples	Holistic, data-driven ICP needed to steer decarbonization; most firms underuse ICP	Advisory perspective; limited empirical evaluation
GHG Protocol (2022)	Cross-industry	Scope 3 accounting guidance	Standard FAQ and calculation guidance	Scope 3 often largest; provides data collection and calculation approaches for value-chain emissions	Guidance; not an empirical study
ADEC Innovations (n.d.)	Cross-industry	Carbon accounting methods for Scope 3	Whitepaper overview	Summarizes methods and advantages of including Scope 3 in inventories	Non-academic; lacks primary data
Reichelstein (2023/updated 2024)	Corporate accounting theory	Carbon accounting balance sheets and flow statements	Conceptual accounting design paper	Proposes GAAP-like carbon statements to track embodied and emitted carbon over time	Not field-tested at scale
CFI (n.d.)	Cross-industry	Carbon/GHG accounting (Scopes 1–3)	Educational explainer	Clarifies definitions and importance of carbon accounting for compliance and capital access	Non-peer-reviewed overview
US EPA (1998)	Municipal solid waste agencies, USA	Full Cost Accounting (FCA)	Six case studies documenting FCA in solid waste management	FCA captures hidden, overhead, past/future costs improving decision-making	Public sector focus; dated contexts
US EPA/ICF (1996)	Electric utility	Full Cost Accounting for planning	Case study documenting incorporation of	FCA monetizes environmental impacts to	Single utility; draft review

	(Ontario Hydro)		environmental costs	inform utility planning decisions	
Horney et al. (CMU) (1998)	Injection molding plant, USA	Full Cost Environmental Accounting	Plant case quantifying scrap-related costs	True scrap costs were ~3× higher than recorded, informing process improvements	Single-site case; older data
Ayinla et al. (2024)	Multi-industry, global	Environmental costing (review)	Systematic literature review (2013–2023)	Environmental accounting moving mainstream; calls for standardized frameworks	Quality variation across sources; review scope limits
Nyakuwanika & Panicker (2025)	Global	Environmental accounting & ESG	PRISMA-based SLR (47 studies)	Carbon accounting supports target-setting; high-quality disclosure linked to financing benefits	Heterogeneous measures; greenwashing risks
Swalih et al. (2024)	Global, multi-sector	EMA for strategic decision-making	Systematic literature review (89 studies)	EMA use evolves from legitimacy to strategic sustainable development	Literature-based; implementation evidence varies
Barani et al. (2025)	Global, meta-analysis	EMA across contexts	Meta-analysis of 36 studies (13,010 obs.)	EMA positively impacts performance; moderated by national maturity and firm size	Publication bias possible; heterogeneity remains
CISL (2025)	Cement industry (UK focus)	Costing/footprinting within decarbonization strategies	Sectoral case study report	Outlines levers (CCS, efficiency, clinker substitution) with implications for cost/carbon	Policy/UK-centric; not a costing method per se
Ulhasanah & Goto (2012)	Cement, Indonesia	MFCA integrated with MFA & LCA	Company-level case with scenario analysis	Industrial symbiosis and MFCA identify eco-efficiency improvements	Older case; limited generalization
Liu et al. (2025)	Cement, China (Xinjiang)	LCA–MFCA integration	Empirical case; Pareto and hypothesis testing	Eco-efficiency improved from 0.8737 to 1.0519 via integrated approach	Single firm; regional context
Rüdele & Wolf (2023)	Automotive suppliers, Austria	Product Carbon Footprint (ISO 14067)	Three product case studies	Low-carbon materials and renewables can cut PCF up to ~80% depending on material	Supplier-specific; limited sample
Muthu (Ed.) (2024)	Multi-industry	Carbon footprint assessment	Edited volume of case studies/best practices	Sectoral methods and mitigation options summarized across industries	Chapter heterogeneity; varying rigor

aPriori (2023)	Discrete manufacturing	Product costing + CO2e simulation	Tool-based case examples	Regional energy mix and design choices alter cost/CO2e trade-offs	Vendor case; not peer-reviewed
Siemens (Case Study) (n.d.)	Industrial products, Germany/global	Product cost management + CO2e	Corporate case report	Integrated costing and CO2e transparency supports eco-design and net-zero goals	Single company; limited methodological detail
UBQ Materials (2025/2026)	Cross-industry guidance	Carbon accounting (Scopes 1–3)	Practitioner guide	Emphasizes Scope 3 challenges and strategic value of robust accounting	Vendor perspective; not empirical
Duan, Li & Zhang (2024/2025)	Global listed firms	Carbon pricing impacts (firm-level)	Triple-difference using staggered policy enactments	Carbon pricing reduces profits/values of high-emission firms; shifts value toward low-emission peers	Policy design heterogeneity: causality relies on identification assumptions
Martinsson et al. (2024)	Manufacturing, Sweden	Carbon tax effects (firm-level)	Firm microdata (26 years); elasticity estimation	Emission-to-pricing elasticity ~2; emissions ~30% higher absent tax; heterogeneity by abatement cost	Country-specific; tax scope variation

The studies reviewed in totality demonstrate the dynamics of environmental and carbon costing among industries, regions, and approaches to methods. The initial background, including ISO (2011) and APO (2014) defined MFCA as an organised method of tracing material flows and improving decision making concerning waste. Later cases of empirical use include Huang et al. (2019), Puspita et al. (2025), Govender (2016) and research in Sri Lanka, Vietnam, and Indonesia that used EMA and MFCA in various manufacturing contexts, all of which found that visibility of costs, efficiency gains, and regulatory and organisational pressures were among the factors. It has been verified by several reviews and meta-analyses (including Mohd Khalid, 2023, Ayinla et al., 2024, Swalih et al., 2024, and Barani et al., 2025) that EMA and MFCA are increasingly used in the world, although the authors identify the necessity to standardise the method and eliminate methodological dispersion. Similar trends in carbon pricing manifest in ICP models by Desjardins and Sinclair Desgagné (2025), Yale CBEY (2019), KPMG (2023), and Arthur D. Little (2024), showing the effect of internal carbon pricing on investment, abatement, and risk management. Expanding the contribution of carbon accounting, the GHG Protocol, ADEC innovations, Reichelstein and CFI, tackle the challenge of measuring Scope 1-3 and suggests more organised disclosure methods. Additional evidence in sector specific to FCA and carbon foot printing studies also supports the contribution of costing systems to enhance the transparency, hidden costs and to encourage eco efficient practises. In the literature, the major weaknesses are the situation-specific case design, lack of consistency in the methods, theoretical, but not empirical test validation, and SME and emerging market gaps.



Findings from the Literature

Standardization and common language: MFCA and carbon accounting frameworks anchor comparability

A common thread is the move away, as an ad hoc system of environmental costing, to standardised systems that provide common terminology, system limits, and step-by-step implementation logic. The bedrock of the definitional process is provided by ISO 14051 (MFCA) which defines material flows and energy flows, separates material cost and system cost and waste costs, and specifies an implementation sequence which firms can pursue; it decreases ambiguity and facilitates within and cross-industry benchmarking (ISO, 2011; methodology: international standard). The ISO 14051 does not however go the extra mile of prescribing precise calculation formulaes and is concerned with the use of decision in the internal context, instead of the external costs (that may exist) in the society but may restrict comparability across heterogeneous production systems (ISO, 2011; limitation: externalities are not included in the scope). The GHG Protocol guidance on Scope 3, a supplement to MFCA that regulates the emissions side, has become the new de facto language in value chain accounting and data collection strategies and compels firms to consider upstream/downstream effects outside factory gates (GHG Protocol, 2022; methodology: standard guidance). Such language is diffused by practitioner explainers (CFI, n.d.; ADEC innovations, n.d.), which enables wider usage; however, not peer reviewed and more of a pedagogic format, which identifies the importance of such validation in empirical environments (CFI, n.d.; ADEC innovations, n.d.; weakness: being secondary/overview in nature). Implication: The common standard layer (cost standard: ISO 14051; emissions standard: GHG Protocol) is the foundation of subsequent methodological integration (e.g., the MFCA+LCA) and organisational control innovations (e.g., internal carbon pricing), although researchers need to be aware of boundary and calculation decisions that form outcomes.

Adoption drivers and organizational/institutional pressures: from legitimacy to strategy

It has been shown that Environmental Management Accounting (EMA) adoption is fuelled by coercive, mimetic, and normative pressures, which is commonly achieved through waste and compliance-oriented agendas, which later are transformed into strategic applications. It is represented by a qualitative case study in Sri Lankan manufacturing, where the stakeholder pressures influence the EMA routines and waste management practises (Seneviratne and Kalpani, 2020; methodology: interviews/observations/document analysis; limitation: single company, possible researcher bias). Evidence of surveys in the pulp and paper industry in Vietnam find organisational resources and regulatory forces among the statistically significant determinants of EMA implementation (Nguyen, 2022; methodology: n=290 firms; limitation: self-reporting and industry specificity). The broader systematic review (20152020) presents the most commonly documented tool as MFCA and summarises drivers/barriers across industries, supporting the idea that adoption is growing in scale as guidance and models increase (Mohd Khalid, 2023; limitation: English language window). According to more recent literature, there has been a strategic inflexion, such that the deployment of EMA is no longer predominantly

symbolic. The development of legitimacy seeking to strategy aligned EMA to sustainable development is tracked by a review of 89 studies (Swalih et al., 2024; methodology: SLR). The positive performance impacts of EMA are further measured in a meta-analysis (36 studies, 13,010 observations) moderated by institutional maturity and firm size, which means that context conditions determine returns to adoption (Barani et al., 2025; limitation: possible publication bias, homogeneity). Implication: Even though institutional pressures tend to be triggering forces of adoption, capability endowment and market/institutional maturity are what makes the difference between EMA being a strategic performance lever and compliance exercise.

Method integration for eco-efficiency: MFCA combined with MFA/LCA improves decision relevance

The second methodological arc is the incorporation of MFCA in the combination with material/impact models to refine decision signals. Indonesian cement in the case of MFCA and MFA plus LCA combining, the opportunities of industrial symbiosis and eco efficacy were identified, which could have been overlooked by a single lens (Ulhasanah and Goto, 2012; method: company case with scenario analysis; limitation: older and single context). The integration of LCA-MFCA, combined with Pareto and hypothesis testing, increased the eco efficiency of Chinese cement (Xinjiang), which rose by 0.8737 and 1.0519, showing the definite increases in case of co-analysis of physical flows and monetary losses (Liu et al., 2025; methodology: empirical case; limitation: in one firm/region). In one of the electronics suppliers in Taiwan, an MFCA case showed that reprocessing glass recycled were more expensive than anticipated, contravening intuitive assumptions of reprocessing being cheaper all the time and process redesign (Huang et al., 2019; methodology: single firm case). At a guidance level, an APO practical manual (Asia Pacific) confirms an increase in the transparency of the material flow with the help of the MFCA and helps reduce waste with the financial profit, which does not have large cross firms' generalizability (APO, 2014; methodology: manual + case). Implication: Hybridization (MFCA + MFA/LCA) maps physical inefficiencies into managerial salient cost hotspots the trade-off is case specificity which will need close replication across sectors to create external validity.

Internal Carbon Pricing (ICP) as a managerial control: aligning investment and abatement

Another notable theme of governance is that Internal Carbon Pricing (ICP) should be used to transfer the cost of carbon within firms and restructure capital budgeting and finance decarbonisation. The formal model of analysis indicates that internal transfer prices on carbon aims to match divisional incentives with corporate abatement objectives, influenced by production and investment decisions (Desjardins and Sinclair Desgagné, 2025; methodology: theory; limitation: no empirical test). Yale CBEY case compendium and frameworks capture cases in which corporates (e.g., Microsoft, SocieteGenerale, airlines) employ internal charges/shadow prices to prioritise low carbon investments and establish revolving decarbonisation funds, but with a wide range of design characteristics (Yale CBEY, 2019; methodology: policy framework + multiple cases; limitation: non-random cases). Practitioner surveys suggest an increasing ICP adoption to cover transition risk and finance renewables, but the complexity of data and methodology options still act as impediments (KPMG, 2023; methodology: whitepaper + survey; limitation: non peer reviewed). There are advisory analyses proposing Scope 1-3 linked ICP to drive enterprise wide decarbonisation, citing that the majority of firms are under using ICP when unrelated to product and supplier level signals (Arthur D. Little, 2024; limitation: advisory viewpoint). New empirical finance studies reveal capital market implications of carbon pricing and carbon management: panel studies in India reveal the declining value of firms in response to higher emissions, with the negative impact mitigated by carbon management (including ICP) practises (Desai et al., 2025; methodology: panel regressions 20142023; limitation: emerging market generalizability). Cross country quasi experimental designs discover profit/value effects of pricing policies, value changing to lower emission peers (Duan, Li and Zhang, 2024/2025; methodology: triple difference using staggered enactments; limitation: identification depends on the policy heterogeneity). Swedish manufacturing long run microdata is an approximation of emissions elastic to price of 2 and about 30% greater counterfactually in the absence of tax, and is evidence of real response to price signals by abatement (Martinsson et al., 2024; methodology: firm level panel; limitation: country/tax design specificity). Implication: ICP is a managerial control system that links costing and strategy, when combined with sound accounting (Scopes 13) it reallocates investment portfolios and has the potential of maintaining firm value within constrained carbon conditions.

Scope 3 and value-chain cost visibility: breadth brings decision power—and complexity

It is agreed that Scope 3 frequently accounts for the bulk of the total footprint, so supplier and downstream data is essential to plausible environmental costing and targeting (GHG Protocol, 2022; methodology: guidance). Practitioner sources point out that value chain information and its conversion into cost/CO 2 e trade-offs are strategically important and not easily achieved methodologically (ADEC Innovations, n.d.; UBQ Materials, 2025/2026; constraint: vendor opinion). Industry specific data models and boundary options revealed by sectoral/edited volumes (Muthu, 2024) reveal that industry specific footprints and cost allocations change significantly due to industry specific data models and boundary choices. Implication: The inclusion of Scope 3 within the costing perimeter will increase the managerial relevance but requires supplier interaction, allocation policy, and data controls that most companies are yet to establish.

Full Cost Accounting (FCA) as an early precursor: uncovering hidden and future costs

Previous FCA experience in the public and utility sector proved that traditional cost systems obscure concealed, overhead and legacy/future costs, transforming investment and pricing choices. The six case studies at municipal level by the EPA of the US indicated that FCA disclosed new overheads and life cycle expenses, which enhanced the level of planning (US EPA, 1998; methodology: multiple cases; limitation: dated/public sector focus). In Ontario Hydro, FCA involved increasing environmental costs in the planning process monetized the impacts, and affected long term utility decisions (US EPA/ICF, 1996; methodology: utility case; limit: single entity/draught). In one injection moulding factory in the US, Full Cost Environmental Accounting has revealed scrap costs 3 times those in books which spurred process enhancements (Honey et al., 1998; methodology: factory case; weakness: one site, old data). Implication: FCA was the forerunner of modern EMA/MFCA in terms of highlighting the importance of addressing externalities and deferred costs in managerial decisions; this tradition is reflected in current proposals of compulsory environmental/cost reporting.

Toward "carbon financial statements": linking physical flows to financial reporting

Recent conceptual accounting studies introduce carbon balance sheets and flow statements under GAAP that follow the same time-based approach to track embodied and emitted carbon, to bridge environmental and financial reporting (Reichelstein, 2023/updated 2024/methodology: conceptual design; limitation: not field tested at scale). Simultaneously, case studies of product level carbon foot printing (ISO 14067) among Austrian automotive suppliers indicate that material substitution and renewable energy can reduce PCF by up to approximately 80 percent to demonstrate that product granular carbon data can transform cost/price/portfolio decisions (Ruedele and Wolf, 2023; methodology: three products cases; limitation: supplier-specific). Implication: The sphere is moving towards integrated environmental financial representations that can be integrated into management control (e.g. ICP), capital budgeting.

Sectoral evidence and tooling: cement, electronics, and discrete manufacturing

Sectoral syntheses confirm that there are direct costing implications of decarbonisation levers. In UK cement, the clinker replacement, energy use, alternative fuels and CCS have dissimilar cost/CO 2e profiles, as do their related use strategies, which demand scenario based costing to be plausible (CISL, 2025; methodology: sectoral case study; limitation: UK/policy centric). Discrete manufacturing vendor/tool cases (aPriori, 2023; Siemens, n.d.) illustrate such benefits can be simulated on the regional energy mix, process choice, and design parameters to reveal cost-CO 2e trade-offs when developing a product but are not peer reviewed or disclosures limited. Implication: Digital costing/foot printing tools are operationalizing the research findings, however, independent validation and transparent ways are critical.

Emerging economy manufacturing and SMEs: materials dominate and waste is a savings lever

In situations where SMEs are resource intensive, the raw material prices prevail, and the waste flows tend to have an untapped saving potential. The MDF coffin manufacturing in Indonesia demonstrated an EMA design that fits into the MFCA, and MEFA/ECA where the largest cost driver was the raw material, and the solid waste was estimated to consume 16.1% of the total costs, indicating that immediate opportunities were available to

improve its efficiency (Puspita et al., 2025; methodology: single case with interviews/observations/measurements; limitation: the short-term focus). South African single organisation research discovered that EMA allowed directing more environmental costs to products, raising the accuracy of prices and managerial focus (Govender, 2016; methodology: survey/case). Implication: To SMEs in emerging markets, MFCA style transparency brings about rapid wins in waste reduction and superior product costing to establish a foundation and ultimate path towards more sophisticated carbon costing at a later time.

Synthesis across themes: from transparency to value

Through the corpus, the pattern is evident; (i) Standardise language (ISO 14051; GHG Protocol) to (ii) Build internal transparency (MFCA/EMA) to (iii) Integrate with impact models (MFCA+LCA/MFA) to (iv) Embed in control systems (ICP, FCA) to (v) Tie to finance and markets (carbon statements; market valuation underpricing). The case research illustrates significant material and cost reductions through MFCA led transparency (Huang et al., 2019; Puspita et al., 2025; Ulhasanah and Goto, 2012; Liu et al., 2025). According to reviews and meta-analyses, the positive performance impact of EMA depends on the maturity of institutions and firm features (Swalih et al., 2024; Barani et al., 2025). Policy quasi experiments and finance oriented studies demonstrate that carbon pricing and strong internalisation systems (such as ICP) insure or improve firm value through redirecting capital away of processes with high emission levels (Desai et al., 2025; Duan, Li and Zhang, 2024/2025; Martinsson et al., 2024). The other gaps are the standardisation of methodology to calculate data, Scope 3 information and the validation of the conceptual proposals with fields on a large scale (ISO, 2011; GHG Protocol, 2022; Reichelstein, 2023/2024).

Methodological Gaps

There are several critical limitations that have been identified in the literature, and they still limit the effectiveness and comparability of environmental and carbon costing practises. One of the key loopholes is that there are no standardised costing principles thus the wide range of diversifications in how companies recognise, quantify and assign costs of the environment and carbon aspects. This is strongly connected with the uneven measurement practise across the industries where various industries use different instruments, limits, and data points and comparing them across industries is challenging. Inadequacy of longitudinal studies also presents a limitation of research to the fact that there is an unfinished comprehension of the financial and environmental effects of switching to these costing systems. The second limitation is that there is poor integration between the cost of carbon and financial reporting which inhibits the capacity of organisations to integrate environmental information in the mainstream accounting and strategy making. Moreover, there is still an underrepresentation of SMEs and emerging markets in the empirical research, although they are increasingly involved in the global value chains and fall prey to sustainability pressures.

DISCUSSION

The results of this systematic review show that the environmental and carbon costing systems have developed into the key systems of enhancing the efficiency of resources, the cost transparency, and the sustainability performance of different industries. The review of 23 studies shows that there is a general trend: organisations implement these systems to ensure that internal material flows are more visible, the accuracy of cost allocation is increased, and because the pressure on organisations and their stakeholders is growing. Nevertheless, the success of these systems highly relies on the quality of the data, the willingness of the managers and how far the costing practises are being implemented strategically and not as a mandate. One of the most important conclusions to be made after the review is that the perspectives on environmental management are shifting as the traditional, reactive management is being replaced by proactive strategic implementation of Environmental Management Accounting (EMA), Material Flow Cost Accounting (MFCA) and carbon costing methods. The early adherents to these systems by many firms are motivated by coerced pressures or pressures of normativity, either by regulation, cost-recovery mandates or as a result of legitimacy issues. However, with time, there are some studies that demonstrate transitioning towards the use of these costing tools in strategic planning, investment appraisal, and optimisation of operations. This change can be observed especially when organisations amalgamate physical flow information (provided by MFCA or MFA) along with financial analysis to unveil concealed inefficiencies, material losses and long-term cost consequences. In spite of this development, the

review shows that there is a great amount of heterogeneity in the methodological strategies, thus the cross-industry comparability is restricted. The lack of standardised costing rules implies that firms tend to establish boundaries, assign costs and measure emissions in varying ways. This is particularly pronounced in the management of Scope 3 emissions which are hard to quantify but take up the bigger portion of the environmental effect in most industries. Different degrees of reliability and usefulness of reported information on environmental costs are brought about by the absence of uniform measurement practises. This is the reason why, in the present state, harmonisation of guidelines and effective verification mechanisms is highly encouraged in the review. Internal Carbon Pricing (ICP) proves to be one of the promising managerial control mechanisms that can be used to connect carbon emissions and the choice of investment. Despite the limited amount of empirical evidence, theoretical and case-based research demonstrated that ICP can assist organisations in allocating resources to low-carbon technologies, deal with transition risk, and align the incentives of the divisions with the corporate climate objectives. Nevertheless, companies still have difficulties related to the data granularity, pricing mechanisms and how to incorporate carbon metrics in the current accounting and budgeting frameworks. One more critical theme is the emerging impact of digital technologies, such as AI-based costing solutions, IoT-driven emission surveillance and automatic carbon reporting solutions. Though these innovations have potential of making accuracy and reporting burdens less, there is limited empirical research in the real-world benefits of these innovations in economy and environment. Its current implementation is often piecemeal and only in pilot projects especially because of the high implementation cost and lack of technical knowledge, of which SMEs and emerging economies face unique challenges. On the whole, the review demonstrates that environmental and carbon costing systems can considerably improve the relevance of decisions in case they are introduced in a systematic manner and on the basis of valid data. Nevertheless, to attain extensive, successful adoption, some long-standing standardisation, methodological incompatibility, and assimilation in the regular financial and strategic planning procedures are critical. The results highlight the necessity to conduct longitudinal research, cross-national comparisons, and empirical validation of digital innovations to develop the sphere and facilitate low-carbon transitions globally.

Research Gaps and Future Directions

Future studies on the topic of environmental and carbon costing processes must shift towards the development of standard and globally agreeable costing rules capable of minimising the levels of methodological inconsistency and enhance comparability efficiency at the inter-industry level. It is also vital that long term studies are required to investigate the long-term performance effects of implementing environmental and carbon costing systems because the available evidence is partly short term and disjointed. The second potential direction is the consideration of digitalization and how new technologies that have emerged like artificial intelligence have the potential to increase accuracy, emission tracking and automated carbon accounting platforms to reduce reporting costs and increase the strength of decision making. The research should also explore the obstacles SMEs encounter which in most cases are inability to fund advanced costing system due to lack of financial capacity, technical support and institutional support as in most cases they are involved and play an important role in the global supply chains. Also, the connexion between the environmental costing practises and the capital market performance is under researched, knowing how the environmentally conscious investors interpret and price environmental cost information may help to explain why environmental cost information should be used to value the firm, to price risks, and to invest sustainably. Comparative studies across countries are also necessary to investigate the ways in which the global regulatory changes like the price of carbon, mandatory ESG reporting and international standards influence adoption behaviour in various institutional settings. Lastly, the gap between environmental costing and enterprise risk management, climate scenario analysis, and strategic cost management tools has much room to be integrated. This kind of integration would help companies to evaluate climate related financial risks in a more systemic way, align cost structure to sustainability objectives and enable more resilient long term strategic planning.

CONCLUSION

This systematisation review of literature has shown that the environmental and carbon costing systems have emerged as increasingly significant tools to organisations that are interested in aligning financial decision making to sustainability objectives. In the literature, these frameworks are Environmental Management

Accounting (EMA), Material Flow Cost Accounting (MFCA), Full Cost Accounting (FCA), and carbon specific approaches, which offer systematic mechanisms of identification, measurement, and allocation of environmental and carbon related costs. Such systems, in addition to increasing the cost visibility, also expose the inefficiencies, aid in optimization of resources, and improve the strategic responses of firms to the climatic related challenges. It has been demonstrated that organisations that integrate such systems tend to realise an increase in their operational efficiency, waste management, and environmental performance, which also supports the strategic importance of the introduction of environmental costs in the mainstream accounting. In the review however, there is also considerable fragmentation and methodological inconsistency. The differences in measurement methods, data quality, Scope 3 emission treatment and practise by the industry decrease comparability and prevent wider adoption. Although new technologies - real time carbon monitoring, AI based costing tools, digitalized material tracking, etc. - hold the promise of greater accuracy, they are yet to be empirically validated. In addition, SMEs and the new economies are still not well represented in the literature, although they are becoming more exposed to the global sustainability pressure. Overall, the results highlight the necessity of standardisation, enhanced regulatory correspondence, and enhanced internalisation of environmental costing in corporate governance, financial reporting, and strategy. To enhance the effectiveness and reliability of green cost accounting, further research in the longitudinal effects, digital innovations, and the cross-country practise will be significant. Consistent and internationally harmonised costing system will finally assist organisations in shifting towards the low carbon and environmentally friendly economic systems.

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