FRAMEWORK WHITE PAPER

Carbon Accounting:

Framework for a Comprehensive New Product- and Entity-Level, Ledger-Based Carbon Accounting System

Working Paper prepared for the Subsidiary Body for Scientific and Technological Advice and the Subsidiary Body for Implementation (SB 62) of the United Nations Framework Convention on Climate Change *(UNFCCC)*

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The EFI Foundation advances technically grounded solutions to climate change through evidence-based analysis, thought leadership, and coalition-building. Under the leadership of Ernest J. Moniz, the 13th U.S. Secretary of Energy, the EFI Foundation conducts rigorous research to accelerate the transition to a low-carbon economy through innovation in technology, policy, and business models. EFI Foundation maintains editorial independence from its public and private sponsors.

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Foreword

Improved carbon accounting is an essential enabler for tracking emissions along the entire supply chain leading to a product (or service) and its use. For example, as low-carbon markets increasingly develop differently across countries and regions, accurate carbon tracking provides the language for monetizing transactions and understanding the risks that underpin investments. This calls for a policy-agnostic and technology-neutral approach based on well-established financial accounting principles. Product-based carbon accounting can be a tool that allows high-fidelity, trusted information transfer along the supply chain, serving both commercial interests and those developing carbon policies and regulations. It is not in itself a policy.

This paper is intended to outline the approach and establish the needed principles for an implementable carbon accounting framework. We hope to inform the process leading to COP30 in Brazil. The COP30 leadership can build on the work of previous COPs by advancing product-based carbon accounting, with an eye towards pivoting to an effective implementation phase and enabling appropriate financial flows to clean energy projects (especially in emerging and developing economies). We hope that our work will contribute constructively to those worthy objectives.

There is considerable literature guiding our work, such as pioneering work by Kaplan and Ramanna. Subsequent EFI Foundation publications will reduce much of this literature to practice and translate carbon accounting into product carbon intensity measures. These publications will follow shortly, well before COP30, in order to further this conversation. We hope that this framework paper can initiate a process to move the critical carbon accounting discussion along at COP30 and beyond.

Ernest J. Moniz

13th U.S. Secretary of Energy

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Introduction

This report highlights the need for, and the outline of, a new comprehensive carbon[a] accounting system. The system:

1. draws from established and widely accepted principles of financial accounting, including the concept of a transaction-based ledger;
2. establishes product-level carbon intensity measures that could be fully integrated into entity-level totals;
3. includes comprehensive coverage of all carbon stocks and flows in all forms of carbon; and
4. provides a tool that can help unlock private sector investment in low carbon product solutions and support a wide range of policymaker and stakeholder interests in a policy-agnostic and technology-neutral manner.

This framework document further describes the concepts of a comprehensive carbon accounting system, including the core governing principles, the ledger concept, establishment of major framework elements, formation of a rule book, and illustrations of how the concepts can be reduced to practice and translated into product carbon intensity measures. This report will be followed by supplemental reports that will provide specifics on the design of the comprehensive accounting system and strategies for implementation and governance.

[a] The use of the term "carbon" in this report is intended to apply to all forms of carbon, including carbon dioxide (CO_2), and carbon and hydrocarbon compounds embodied in liquid and solid materials.

The Growing Need for a Comprehensive Carbon Accounting System

There is increasing global interest and activity focused on actions to incorporate the carbon characteristics of commodities, products and services into global trade and economic competitiveness policies.

Product carbon intensity measures provide a new tool to mobilize private sector investment in lower carbon commodities and products while meeting the growing demand for energy. COP 30 provides the opportunity to advance the concept of product-level carbon accounting to promote globally aligned carbon accounting metrics that support scaling up high integrity carbon markets (voluntary and compliance).

There currently is a stream of ongoing activities that are aimed in this direction, but they could greatly benefit from stronger leadership and cohesiveness. Current activities include:

- In 2026, the European Commission (EC) plans to implement a carbon border adjustment mechanism (CBAM) of carbon emission intensity standards for imported cement, iron and steel, aluminum, fertilizers, hydrogen, and electricity imported into European Union (EU) member countries. The CBAM is intended to provide a level playing field for European firms as they transition to production of lower carbon commodities and products. The EC also is proposing new legislation that would establish a voluntary program of product carbon intensity labeling, beginning with steel.
- In August 2024, China adopted a new national standard on product carbon footprints. This new standard will serve as the basis for developing product-specific footprint methodologies. China aims to develop product-level carbon standards for 50 key products in 2025 and expand to 200 products by 2030, with a view towards increasing its competitiveness in global markets.

Currently, about one-quarter of global CO_2 emissions are subject to some form of carbon emissions pricing, generating over $100 billion in total compliance revenue in 2024,[1] primarily driven by the EU Emissions Trading System (ETS). In concert with these actions, the EC is in the process of implementing new entity-level mandatory greenhouse gas disclosure requirements for corporate entities within EU member countries.

While the United States continues to rely on a combination of private sector entity-level GHG voluntary emissions reduction targets and actions by state and local governments,

businesses engaged in global trade will need to develop improved measures of the carbon intensity of their products. Roughly two-thirds of Fortune 500 companies have set net-zero goals or commitments. Many corporate plans rely on trading carbon offset credits in voluntary markets to meet these targets. Globally, the cumulative volume of traded carbon credits reached 2.4 billion credits in 2023, representing just under 2,500 $MtCO_2e$[2] (or about 7% of global annual emissions in 2023 alone).[3]

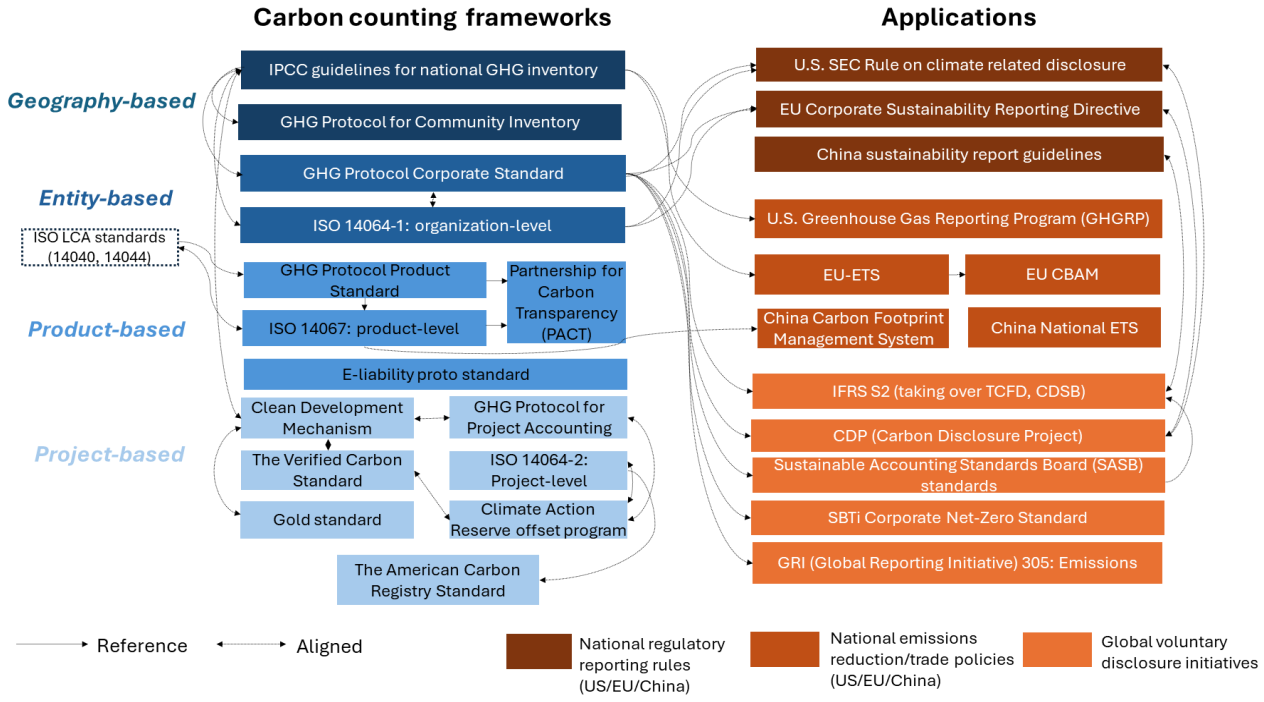
Product carbon intensity measures could become a driver for increased investment in lower carbon solutions. According to the International Energy Agency's June 2025 *World Energy Investment*, global investment in clean energy technologies[b] will reach $2.2 trillion this year, reflecting efforts to reduce emissions as well as the growing influence of industrial policy and energy security concerns.[4] Global investment in oil, natural gas, and coal is expected to reach $1.1 trillion. China is by far the largest driver of the growth in clean energy investment, with the country's share of global clean energy spending rising from a quarter to a third over the last decade.[5]

The absence of a uniform and verifiable product carbon accounting system poses serious challenges for competitiveness in global markets. Establishing product carbon intensity as a key performance indicator (KPI) enables benchmarking and identification of new capital investment opportunities to reduce carbon and improve manufacturing cost efficiency. Absent comparable KPIs, a commodity or product that is considered lower carbon intensity in China, for example, may not be so in Europe or the United States. One study, for example, concluded that "on average, U.S.-manufactured goods are more than twice as carbon-efficient as the world average and about four times as efficient as those made in China."[6] A recent S&P Global Commodity Insights paper underscored the need for improved product-level carbon accounting, noting that "A carbon differentiated market is a world where buyers and sellers can compare, trust, and assign value to the GHG emissions associated with commodities and products."[7]

The combination of emerging government requirements and market forces points to the need for complete, accurate, comparable and verifiable carbon accounting. There are currently more than a dozen frameworks for counting and reporting emissions, with separate guidelines for country-level, entity-level, product-level and project-level reporting (Figure 1). Other than the E-liability proto standard listed in the Figure, these guidelines are largely purpose-built for specific applications, lack integration, and fall short of meeting the principles and standards that are widely accepted in financial accounting.

[b] The IEA defines "clean technologies" as renewables, nuclear, grids, storage, low-emissions fuels, efficiency and electrification.

Figure 1. Multiple carbon counting frameworks purpose built for a variety of applications



Source: EFI Foundation

Most current entity-level emissions reporting relies upon the Greenhouse Gas Protocol (GHGP) guidelines. The GHGP guidelines were established with the original purpose of enabling entities to develop and publicly disclose greenhouse gas emissions inventories. They were not designed as a tool for rigorous carbon accounting.

Current efforts to improve carbon counting and reporting are fragmented. COP 30 could provide the opportunity to raise this effort. The GHGP has a multi-year process underway to update the GHGP Corporate standard for entity-level reporting, including updated guidelines for reporting Scope 2 emissions resulting from the use of electricity and fuels. Separately, the EC has moved to establish product carbon intensity standards for CBAM based on industry-wide averages derived from carbon life cycle modeling of products.

China has adopted its own methodology to support its product-level carbon standards. Recognizing the need for further development of appropriate guidelines, the EC recently proposed “to simplify and harmonise carbon accounting methodologies” with work beginning in Q4 2025.[8] While these efforts should improve the quality of reporting, there are structural limitations in the GHG Corporate Standard and Product Standard protocols

that do not allow for comprehensive product-level carbon accounting or integration of product-level and entity-level reports. Several principal issues are identified in Box 1.

Box 1. Limitations of Current Reporting Guidelines

Current carbon inventory and reporting frameworks lack many of the foundational characteristics of financial accounting – characteristics which must also underpin any successful carbon accounting system.

- Current frameworks are purpose-built, with guidelines for collecting and reporting emissions designed to serve a single policy or industry. Consequently, emissions reporting can be inconsistent and incomparable.
- Current frameworks which focus on entity-level emissions lack clear and consistent boundaries of time and space. Reporting time periods combine past, present, and future emissions data; reporting boundaries may expand or contract to include activities outside of an entity's management. These inconsistencies further limit verifiability and comparability.
- Current entity-level emissions reports may contain gaps because they do not account for all emissions from all stocks and flows of embodied carbon within an entity.
- Current frameworks allow broad flexibility in data collection protocols, affecting data quality and limiting the effectiveness of comparisons. Flexibilities include allowing entities to set different thresholds for data reporting and using industrywide and national averages to substitute for entity-specific data.
- Current reporting systems lack the rigorous verification standards necessary to instill confidence in product purchasers and third-party investors. For example, some guidelines allow for self-verification as a substitute for third-party verification.

The Architecture of a Comprehensive New Carbon Accounting System

What would a comprehensive new carbon accounting system look like?

A product- and entity-level, ledger-based carbon accounting system is a comprehensive approach for organizing, recording, and reporting complete, accurate and verifiable information on all stocks and flows of all forms of carbon in products within the organizational boundaries of an entity and within a defined time period.

A comprehensive carbon accounting system is based on a set of principles, conventions, and rules. The design would be governed by a set of principles modeled from well-established and wide-adopted principles for financial accounting. Implementation would be governed by a Rule Book, similar in concept to the rule book for Generally Accepted Accounting Principles (GAAP). A large body of literature proposing differentiated approaches has been put forward, e.g., Kaplan and Ramanna,[9, 10] Reichelstein,[11] Penman,[12] and Jia et al.[13]

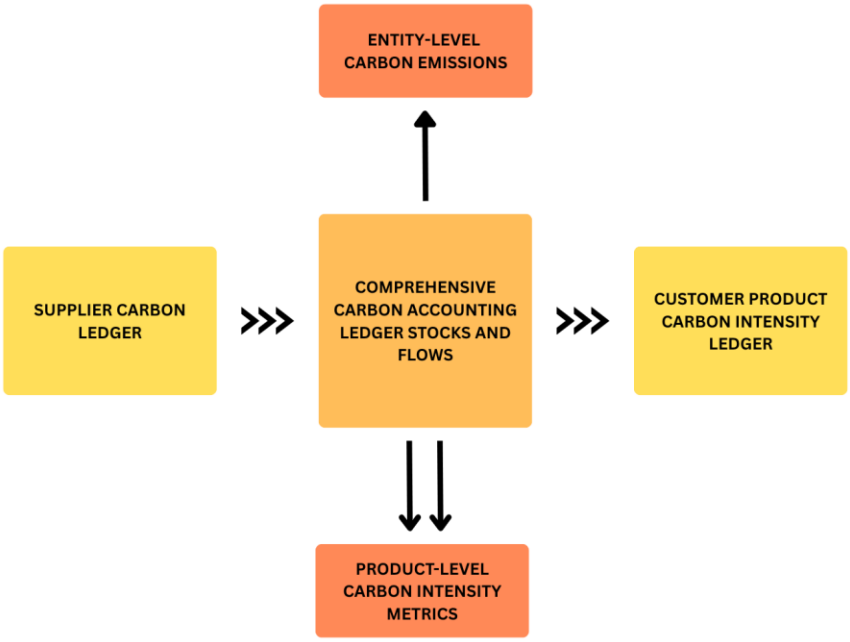
The principal characteristics of a comprehensive new product- and entity-level, ledger-based accounting system include:

- accounting for all stocks and flows of carbon (in all forms) within an entity;
- product-specific carbon accounting to support product carbon intensity measures;
- activity-based allocation rules to account separately for multiple product streams, assigning carbon impacts of entity-wide support and overhead activities to individual products;
- integration of product-level carbon intensity measures into an entity-wide total without gaps or overlaps in the data;
- clear and consistent application in space and time, i.e. full coverage of:
    - gate-to-gate operations of the entity, mirroring the legal and financial boundaries of the entity; and
    - all transactions as they occur within a defined reporting period, providing a complete snapshot of carbon stocks and flows within that period.

The Comprehensive Carbon Accounting System operates in both a vertical dimension (reporting product-level carbon intensity that can be aggregated into entity-level totals) and a horizontal dimension (reporting the transfer of carbon records from entity-to-entity within

a product value chain). In both dimensions, the reporting is complete without gaps or overlaps. (See Figure 2).

Figure 2. The Schematic Diagram of a comprehensive accounting framework



Source: EFI Foundation

The Carbon Ledger

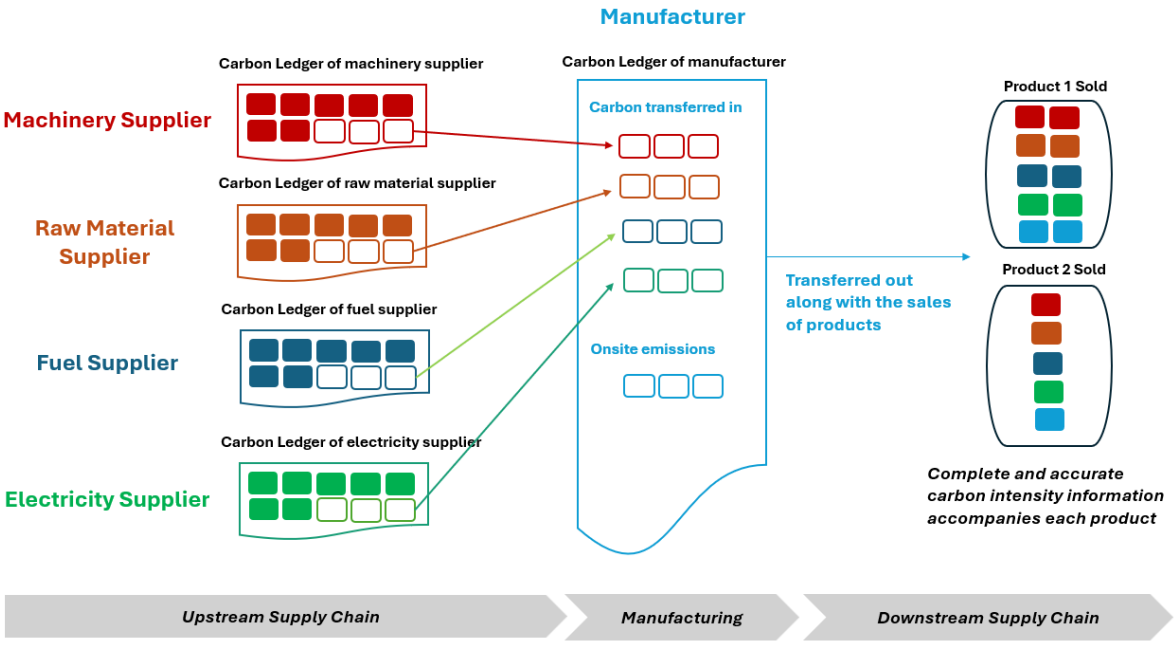
The central element that enables these characteristics is a ledger. The ledger holds a chart of accounts derived from a comprehensive carbon mass balance of the product development process. The ledger holds all carbon-related transactions, including all flows of carbon entering and exiting the entity and the various forms of carbon stocks within the entity. The ledger records all transactions as they occur within the defined accounting period.

Ledger entries follow the carbon mass balance of the entity. As carbon enters the entity's gate, it is recorded in the ledger. Changes in the stock of carbon as it moves through the entity are recorded as it passes from one stage of the process to the next. Finished products are recorded as leaving the gate.[c] The data on the product carbon footprint is then transferred from the entity's ledger to the ledger of the entity's customer, and ultimately to

[c] The ledger could be used equivalently for services, which would merely lack any physical carbon content.

the final consumer. The process of transferring carbon across the ledgers of each entity in the product value chain is illustrated in Figure 3.

Figure 3. Illustration of product-level carbon ledger process



Source: EFI Foundation, adapted from Kaplan and Ramanna[14]

Transactions external to the entity's operation, such as the purchase or sale of carbon offsets generated off-site, including carbon removals but excluding avoidances, can be added to the ledger and incorporated into the product carbon intensity calculations. The rules for recording offsets would be established in the carbon accounting rule book and described in more detail in a subsequent paper.

At the end of the reporting period, which can be set for any time interval (e.g. daily, monthly), the ledger supports complete and accurate reporting on:

- product-level carbon intensity of products leaving the entity's gate;
- entity-level reports on total carbon emissions generated within the entity; and
- other reports on stocks and flows of carbon within the entity.

The ledger also provides an open book for third-party verification of all carbon-related transactions.

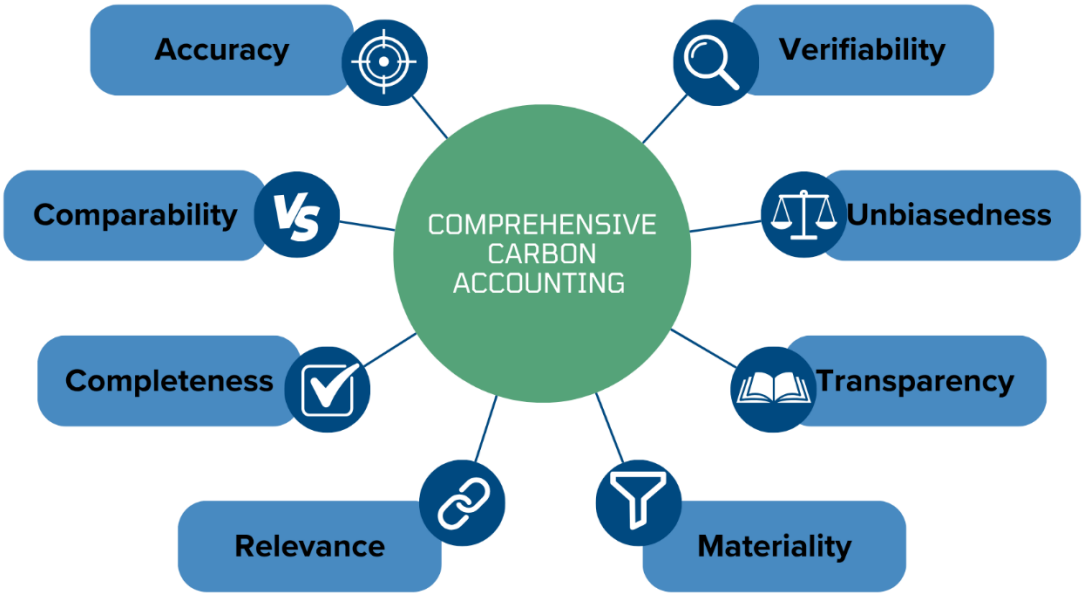
Core Principles

The starting point for the design of a ledger-based comprehensive accounting system is a statement of core principles. The core principles serve three purposes:

1. Setting guardrails for the ledger design and rule book;
2. Providing a yardstick for resolving issues – an objective standard for dispute resolution; and
3. Establish a starting point for building consensus

Financial accounting standards, such as GAAP, are governed by a set of general principles of accounting. Current carbon inventory and disclosure guidelines—including the IPCC guidelines for country-level inventories, the Greenhouse Gas Protocol, and the International Organization for Standardization (ISO) guidelines—also cite governing principles. Drawing from these examples, eight core principles (illustrated in Figure 4) form the governance framework for a product- and entity-level, ledger-based carbon accounting system.

Figure 4. Principles of the Comprehensive Carbon Accounting System



Source: EFI Foundation

The eight principles include:

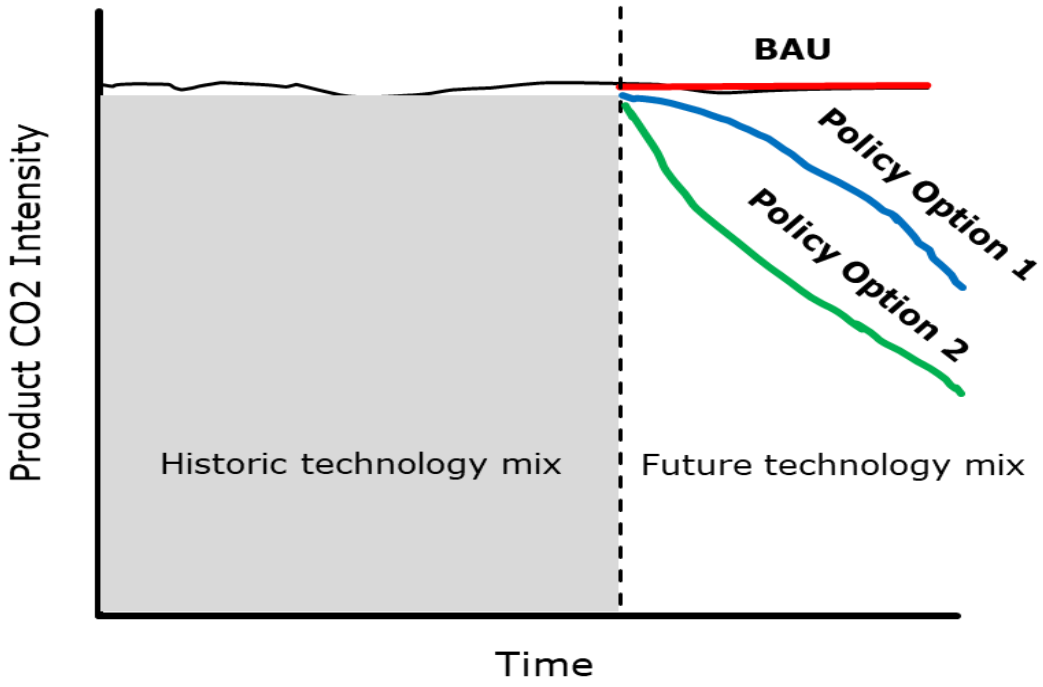
- **Relevance** – The ledger should include all information necessary to support decision-making by the responsible entity.
- **Materiality** – The ledger may contain a threshold level for disaggregation of data to *de minimis* levels that otherwise would not be significant.
- **Accuracy** – The quality of data recorded in the ledger should have a minimum of uncertainty.
- **Unbiasedness** – Ledger data should be collected and recorded in a neutral manner with no deliberate or systemic bias in the data.
- **Completeness** – The ledger should include carbon data from all carbon sources and related activities
- **Transparency** – The ledger should include all appropriate supporting documentation of the basis for the recorded carbon data.
- **Comparability** – Ledger information should produce comparable results across products, regardless of reporting entity, by applying the same set of standards and rules. Additionally, information should be able to compare one product across time.
- **Verifiability** – Ledger records should be sufficiently robust (as described in the principles above) to enable assurance by third party reviewers.

The core principles should be implemented **pragmatically, affordably**, and in a **recursive manner** —encouraging learning, evolution and diffusion.

Applying the Comprehensive Carbon Accounting System to Product Carbon Intensity Measures

A product carbon intensity standard (PCIS), based on units of carbon per unit of product, can be established from the carbon accounting ledger. A standard can then be set to require a reduction in the product carbon intensity over time, creating competition among all producers to meet increasingly stringent requirements.

Figure 5. Conceptual illustration of product carbon intensity standard (PCIS)



Source: EFI Foundation

Product intensity standards allow capital investment to flow to the most cost-effective solutions, achieving the stated requirement while continuing to meet demand. Product intensity standards have been used successfully across many sectors of the economy, including energy efficiency (vehicle miles per gallon) and nutrition (calories per serving). One example of a product intensity standard driving innovation was the intensity standard to reduce the sulfur content of marine fuels (see Box 2).

Box 2. Example of a product intensity standard: Marine fuels

In the 2010s, the International Maritime Organization (IMO) reduced the limit of sulfur content in marine fuels from 3.5% to 0.5%. The IMO engaged industry over more than a decade on the change and included them in the study of its feasibility, giving suppliers time to consider how best to meet the new specification and make the necessary investments.[15] Multiple solutions were developed, including fuel hydrotreating, alternate feeds for marine fuels, on-board scrubbers, and alternate fuel vessels.[16] By 2020, when the specifications took effect, the IMO reported only 55 cases of compliant fuel being unavailable among the 60,000 ships driving global trade, according to the IMO.

A verifiable PCIS promotes global competitiveness for carbon-differentiated commodities and products by enhancing market transparency and encouraging capital deployment efficiency. Adoption of a comprehensive product- and entity-level ledger-based product carbon accounting system is the key to enable a verifiable PCIS.

Implementation Pathway for the Comprehensive Carbon Accounting System

Scaling a new comprehensive product- and entity-level, ledger-based carbon accounting system across products, industries, and national borders will take time, and will require the guidance of some form of governing process.

The global reach of a uniform carbon accounting system will require governance through some form of international process and organization. The governance structure needs to address key elements including (1) legal structure, (2) funding, (3) personnel and (4) policies and procedures. [17]

Standards-setting efforts in other fields have combined organic efforts by interested parties (e.g., professional organizations, private sector entities, nongovernmental organizations) with some form of governmental direction. Existing quasi-governmental or industry-wide voluntary organizations provide possible models that could serve as the starting point for establishing a governance structure for carbon accounting. These include:

- Technical standards organizations, such as the ISO or the International Labor Organization (ILO).;
- Financial accounting standards-setting organizations, such as the Financial Accounting Standards Board (FASB) in the U.S. or the International Accounting Standards Board (IASB) in the EU and other countries; or
- Industry sector-specific organizations, such as the IMO or the Institute for Nuclear Power Operations (INPO).

These models typically have some form of governmental involvement in their formation and/or operation. The GHG Protocol governance, by comparison, has been a voluntary initiative led by two non-governmental organizations, the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD). A subsequent discussion paper will examine governance issues in greater detail.

The timetable for implementing a comprehensive product- and entity-level, ledger-based carbon accounting system likely will need to follow a pragmatic multistage approach, including:

- ***An early adoption phase***, with the formation of a steering committee to establish an initial set of product-level carbon accounting standards, including an initial chart of accounts, ledger template, and rule book. The initial version could then be adopted by a small number of early movers within selected product groups.
- ***An expansion phase***, as experience is gained by the early adopters, including verification of "reasonable assurance" in initial audit reports. This phase could include the evolution and expansion of the rule book and its adoption by additional entities and products.
- ***A large-scale diffusion phase***, where carbon accounting systems are in place for global products and services representing a large majority of global carbon emissions. The recursive nature of carbon accounting could also lead to significant across-the-board improvements in data quality.

The early phases could be initiated through the formation of a voluntary organization. Early governmental intervention, however, could jump-start the implementation effort, such as through the formation of a working group of international experts.

Conclusion

Just as financial accounting is a fundamental tool to support decision-making across the private sector, a comprehensive product- and entity-level ledger-based carbon accounting system can provide a trusted, universal tool to establish the product carbon intensity measures that can catalyze the transition to a carbon-differentiated economy.

The establishment of a comprehensive product- and entity-level ledger-based carbon accounting system— including principles, standards, framework elements, a rule book, and governance—can be informed by financial accounting principles, with the support of scientific and engineering practices. Implementation of the system will support the establishment of product carbon intensity measures. These metrics allow buyers and sellers to differentiate based on carbon in transactions and unlock new investments in lower-carbon solutions required to meet growing energy demand while lowering emissions.

Follow-on EFI Foundation reports will provide supplemental details of how the concept of a comprehensive new product- and entity-level ledger-based carbon accounting can be reduced to practice, case studies of how carbon accounting can be applied to establish product carbon intensity measures, and how a new carbon accounting system can be governed and implemented, starting with the formation of a working group of international experts.

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