

Accounting for Carbon

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Accounting for Carbon

Abstract. This paper designs accounting that reports an entity's progress in reducing carbon emissions (or not). In the same form as financial accounting, it reports a balance sheet where assets for reducing carbon are compared to liabilities for carbon emissions, with the difference reporting an entity's net position in carbon and its progress in reaching milestones such as a net-zero carbon goal. The quasi-income statement reports the periodic emissions with explanatory detail. The balance sheet complements the income statement, providing more information than the current period's net emissions: By recognizing assets, an entity gets credit for current efforts to reduce carbon that are realized only later, thus dealing with the timing problem between investing in carbon reduction and its effect. That is offset by obligations to reduce carbon in the future. The accounting is designed for responsibility reporting with attractive incentive and monitoring features. It provides a framework for pro forma (budgeting) of carbon reducing strategies, setting benchmarks against which actual results of strategies can be evaluated. It allows for consolidation across entities to report on carbon for specific groups such as industries. It facilitates comparisons with financial metrics to evaluate trade-offs and "sustainability" more generally.

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Accounting for Carbon

Introduction

This paper designs an accounting system for tracking and reporting an entity's carbon emissions and its efforts to reduce emissions. Effectively, the system places the Greenhouse Gas (GHG) protocols in a responsibility accounting system with incentive compatibility features, enhancing the carbon reporting and monitoring for which the protocols were presumably designed.

The double-entry system parallels that for financial accounting, reporting a balance sheet and income statement but with the numbers in units of CO₂ from carbon emissions (with equivalents from other green-house gasses weighted in). Balance sheet liabilities are recorded for emissions, with the corresponding double-entry "debit" a charge to an income statement. Assets are recorded for remediation of carbon emissions, with the corresponding double-entry "credit" going to the income statement to offset the charge for emissions when the remediation efforts are effective. The difference between the two income statement effects, footed in the statement, is the entity's net contribution to carbon emissions in a reporting period. Assets are booked for investments to remove carbon in the future, so an entity is evaluated, not only on its current emissions but also on efforts to reduce emissions in the future; the accounting thus provides information on an entity's likely position in carbon in the future as it proceeds to zero-net-carbon goals (futures accounting rather than just spot accounting). However, the effects of those efforts are recognized in the income statement only when realized, so there is a settling up of carbon removal strategies against actuals, yielding performance metrics that discipline those strategies and carbon removal promises often viewed with skepticism.

As in financial accounting, the income statement "bottom line" number closes to the "bottom line" equity in the balance sheet that reports the accumulated carbon position to date in a number mirroring shareholders' equity in financial reporting. Double entry with its remarkable features governs such that the income statement articulates with the balance sheet: The net carbon for a period explains the change in assets net of liabilities and adds to "shareholders' equity" with the equity number then tracking the net carbon position overtime.

This shareholders' equity might be labelled the carbon footprint, but the term used in financial statements informs. With financial reporting, this bottom-line number in the balance sheet states to whom the reports are primarily reported: The financial accounting system is one that tracks the shareholders' interest, updating their equity each period with the change in their interest. The carbon accounting differs by redefining in whose interest the accounting is done. That is you and me, more broadly society, who collectively are concerned about the effects of carbon emissions. So entities are viewed as reporting to society about their contribution to net carbon: Society is the shareholder, though better referred to as the stakeholder. The stakeholders' equity number is society's carbon position in the entity or, from the entity's viewpoint its contribution of net carbon in society's interest. The stakeholders' equity can be positive or negative though likely to be negative for many entities.¹ With the presumption that net carbon is "bad," a negative balance indicates a reduction in the "net worth" of the entity for society and a net liability to society by the entity. A positive balance conveys a net contribution to reducing carbon in the atmosphere, a benefit to society.

That said, the accounting is neutral as to specific users of the carbon statements. They could be a regulatory agency (a presumed agent for society), carbon tax authorities, climate activists, litigants, lenders, investors, or consumers considering carbon production in their purchasing decisions. And the entity itself is informed about its position in carbon and how it got there. The proposed accounting is also neutral on the voluntary versus regulated reporting question. Without regulation, it guides voluntary reporting to convey an entity's position in carbon (against claims otherwise) that is more definitive than qualitative disclosures.

The design applies to all entities whether they be business firms and their divisions, non-profits, governments, or government departments. The income statement net number reports the progress in a reporting period towards an entity's goal. That is often stated in the form of a target of "net zero by 2050," for example, or in commitments by governments in agreed protocols. However, that is complemented with a balance-sheet number for the cumulative progress at each date. At a target date for zero emissions, the balance sheet maintains the record for cumulative net emissions

¹ As of 2023, reports put annual world-wide carbon emissions at 40 billion tons of CO₂ relative to one billion in carbon reduction. That is a flow number, however.

even though the periodic contribution has gone to zero. Some firms do announce a goal for cumulative net emissions. Reporting a balance sheet number can expand the practice.

The proposed accounting responds to the European Corporate Sustainable Reporting Directive (CSRD) which aims to bring sustainability reporting standards in line with financial reporting standards. However, that initiative is directed towards disclosure rather than accounting, as in the European climate standard, ESRS E1. The International Sustainable Standards Board (ISSB) recently issued IFRS S2 with a similar disclosure orientation. In financial reporting, disclosure is a remedy when formal accounting does not convey relevant information. The paper explores how the information in carbon disclosures might be conveyed in an accounting system that mirrors the financial reporting system.

To be clear, the paper lays out a design of what a comprehensive accounting for carbon would look like if the accountant has reliable, verifiable, and auditable measures for the carbon statement elements. If this is not so, some elements in the accounts might have to be excluded, defaulting to qualitative disclosure but losing potential information. So the design stands as a prescription of the information that could be conveyed with reliable measurement. That is so with financial accounting where the criterion of measurement uncertainty is applied for recognizing assets and liabilities, with intangible assets and off-balance contingent sheet liabilities being examples of nonrecognition.

Before getting into detail, we highlight the main features of the accounting system.

Features of the Carbon Accounting

An accounting system cannot be designed without a firm understanding of whom the reports are going to and for what purpose. That defines whose interests, whose equity, is being tracked in the balance sheet and to whose benefit (or loss) the net number in the income statement accrues. The carbon accounting here is reporting to society, current and future generations who potentially suffer the effects of carbon emissions. It is responsibility accounting to those interests by entities generating emissions.

That colors the interpretation of assets, liabilities, and “income” in the income statement. A balance-sheet asset is one produced by the entity as a contribution to society’s endeavor in reducing carbon. It is not an asset of the entity in its own interest to generate future benefits for its equity

holders (other than their interest, as part of society, in reducing carbon). And so for liabilities; these are the entity's addition to society's liabilities to reduce carbon if the entity does not do so (that the government, say, would have to deal with under its granted powers on behalf of taxpayers). As the entity is an agent in the endeavor, the accounts are also a reporting from the agent to the stakeholders of its contribution to society's endeavor, much like financial accounts are a report to shareholders of the stewardship of management in their interests.

Here are the main features of the accounting system:

Responsibility reporting. The system fulfills the accounting function of accountability, also known as responsibility accounting. This is the perspective of the entity as an agent in the carbon reducing endeavor. But the responsibility accounting is taken further. Carbon reduction goals settle up against the accounting—budget versus actual—with the reported variances requiring not only explanation but also a modification of remediation plans and/or promises. With this control feature, the reporting cuts across greenwashing. For a firm selling carbon credits, the accounting adds credibility (or otherwise) to the claim that it is actually removing carbon from the atmosphere. These are features of other carbon reporting schemes and satisfy the time-consistent corporate carbon reporting (TCCR) requirements in Comello, Reichelstein, and Reichelstein (2023) and the 2017 disclosure principles of the Taskforce for Climate-Related Financial Disclosure (TCFD). But now with more accounting detail.

The “principals” in this responsibility reporting might be regulatory agencies, and the transparency with the accounting serves such agencies. But it also serves reporting entities who can argue their case on concrete grounds. Politics inevitably intervene with regulation, with regulatory capture also a possibility, but the transparency in the system can (hopefully) keep politicians in check. So the carbon reporting also helps society to monitor its agents, the government.

Stocks and flows reporting. The proposed accounting has the reporting features of financial accounting, with the same balance-sheet reporting of “where we are now” (stocks) and income-statement reporting of “what has been added” (flows), but with a different unit of measurement and a different stakeholder. With information on accumulated net carbon (stocks) in the carbon balance sheet, the accounting conveys the direction in which an entity is heading in the interests

of these stakeholders and its progress to date of meeting emission goals.² As a parallel to financial reporting, it is easily interpretable. It is potentially auditable and in the same form as that for financial statement audits.

Enhanced information on carbon reduction. The reporting of assets in a balance sheet communicates efforts to reduce carbon in the future, enhancing the reporting of carbon reduction. So an entity is not judged solely on its current emissions but also on expected future emission reduction from its investment efforts. Indeed, building carbon-reducing technology to reduce carbon in the future might itself generate current emissions. Balance sheet assets expand the information for ESG ratings, many of which have come under criticism for their deficiencies. They are information for the pricing of green bonds, for the holders of those bonds who monitor conformance with covenants requiring green execution, and for a bank lending with that perspective. For firms seeking green capital, the accounting provides transparency much like financial reports do for raising financial capital. The asset accounting also informs an emissions monitoring agency and a regulator taxing carbon: Rather than regulatory decisions (and taxes) based on current emissions that might discourage economic activity, an entity is given credit for efforts to reduce future carbon emissions, possibly promoting the use of carbon tax credits for doing so. Investors assessing a brown-green risk premium in buying a firm's stock are informed; the risk premium is not just based on current emissions but on green-from-brown transitioning so requires information about projected future emissions.³ As in financial reporting, that asset effect is not recognized in the income statement (as a flow) until it is realized. Thus the system accommodates the timing difference between efforts to reduce carbon and its actual effects.

Double entry information. As in the (stocks and flows) financial reporting system, stakeholders' equity is explained twice, by additions in the income statement that close to equity and by assets relative to liabilities in the balance sheet: double entry. That is a control feature: If that equivalence is not satisfied, there is something wrong. However, it also conveys information. Thus, for example, just as debt cannot be evaluated without the assets that back it up, so claims about an entity's liability for carbon must consider the assets that net against it. Reporting the periodic net

² The climate disclosure rule issued by the U.S. Securities and Exchange Commission (SEC) in March 2024 seeks information on how a firm "made progress toward achieving a target."

³ See Zhang (2024) on the pricing of carbon transition is and the need for forward looking information.

carbon in the income statement relative to the assets and liabilities position adds perspective, much like a coverage ratio modifies the interpretation of the debt-to-assets ratio. Detailing the assets and liabilities and the periodic net carbon adds further information. The Carbon Statement Analysis section elaborates.

Aggregation. Sustainability reporting at present involves disclosure of numerous measures, 830 mandatory “data points” and 279 voluntary, with 247 quantitative metrics in the ESRS according an EFRAG count, although many of these involve sustainability metrics other than GHG emissions. But there is little meaningful aggregation to aid the digestion, as pointed out by Wagenhofer (2023). Aggregation paints a wider, cohesive picture. Like elements aggregate to meaningful subtotals within the income statement and balance sheet which, in turn, sum to the “bottom-line” totals in those statements to explain what determines the bottom line.

Recognition: Scope 1 emissions. Accounting applies principles for the “recognition” of what enters a reporting system and what does not. That defines the information conveyed by the report. The carbon accounting is primarily for Scope 1 emissions, those for which the entity is directly responsible and must “give an account” to stakeholders.

Recognition: Scope 2 emissions. The Greenhouse Gas (GHG) Protocols carve our Scope 2 emissions from upstream emissions, those emitted in electricity, steam, heat, and cooling purchased. These are not directly included in the accounting here for they are not emissions for which the entity is directly responsible, and combining these with Scope 1 emissions involves double counting of carbon from entities reporting along the stream. That said, the proposed reporting also tracks Scope 2 emissions separated from Scope 1 as a check on incentives: An entity could reduce Scope 1 emissions by outsourcing carbon producing activities upstream, thus gaming the system. The added reporting of Scope 2 emissions satisfies the March 2024 SEC rule on climate-related disclosures.

Recognition: Scope 3 emissions. Scope 3 emissions from upstream or downstream, other than the Scope 2 carve out from upstream, are not reported in the system for several reasons. First, of course, they are not those for which the entity is responsible; they are not in the control of the entity. Second, they are difficult to estimate, with the accounting principle of measurement uncertainty then applied. That is particularly acute in business-to-consumer transactions as the consumer’s use of a product and the consequent emissions are highly variable and unpredictable.

Third, emissions in business-to-business transactions are accounted for as Scope 1 emissions in those upstream and downstream entities so booking those emissions would be double counting.

Connection to financial reporting. Society creates entities for benefits to specific interests, and these are often reported in a financial reporting system. That is also a responsibility reporting system (to shareholders and others). With the same system as financial reporting but with different units of account, the carbon accounting promotes an assessment of trade-offs against those other benefits. That puts Chief Sustainability Officers and Chief Financial Officers on the same platform. It serves investors keen to reduce carbon in a for-profit firm but aware of tradeoffs. For society, net carbon from a business can be compared to its returns to society, to capital and labor and to government revenue in taxes, that are reported in the business's financial accounting system. Accordingly, in this "double materiality" perspective, net carbon is evaluated not as an absolute but relative to the benefits in which society also has interests, as will be detailed; the trade-offs address the economics of carbon and put the politics into perspective. That promotes thinking of efficiencies in both the pursuit of profit and the pursuit of carbon reduction. The connection of carbon accounting to financial accounting is the key issue behind the creation of the Integrated Reporting and Connectivity Council (IRFC) established by the IASB in 2022. The EFRAG Connectivity Advisory Panel was established in 2023 with similar intentions.⁴

The comparison of carbon statements with financial statements provides information to an investor concerned with gaining wealth for retirement but also concerned with the effect of climate change on the quality of life in retirement.⁵ For this investor, a firm that generates profits while contributing to carbon reduction might be preferred as an investment to a firm with higher profits and increasing financial shareholders' equity but an increasingly negative carbon stakeholders' equity. Or otherwise for another investor. A debt investor or a bank looking for green lending might also be concerned about credit risk conveyed by financial statements. So an asset-to-liability ratio from the carbon accounting might be evaluated against the debt-to-assets ratio in the financial reports. And that comparison might be complemented with the net carbon coverage ratio in the carbon statements to the coverage ratio in the financial statements. A similar tradeoff faces

⁴ With a different objective in mind, the accounting here does not get to the granular level of connecting each line item in financial statements to its corresponding carbon contribution as in Distler, Ernstberger, Keiling, Müller, and Sbazo (2024).

⁵ Hart and Zingales (2017) and Broccardo, Hart, and Zingales (2022) model such shareholders and the social desirability of outcomes from actions that result from these preferences.

governments. A government that views corporate profits as a contribution to GDP (and tax revenue) can also be concerned about carbon produced in generating GDP. Again, the Carbon Statement Analysis section elaborates.

Pro forma accounting for carbon emissions planning. The accounting system reports on the current position of an entity, both stocks and flows, but it is also a system in which strategies and their effects in the future can be modelled. That is the case with financial accounting where future earnings and book value are modelled under a business strategy. With determinants of net emissions in line items in carbon statements, the modeling is a statement of how a strategy will achieve its carbon projection goals (or not); rather than just a stated net-zero goal, pro forma carbon statements show how an entity plans to achieve that goal. Actual and pro forma numbers are then compared as time proceeds, reporting on the success of the strategy and inducing its modification. That, in turn, disciplines the strategy and statements about net emission goals.

Consolidation. An appealing feature of the proposed accounting is that it facilitates consolidated accounting over reporting entities, yielding an aggregate number that conveys a group's total net contribution to society in dealing with carbon emissions. The aggregation up to group level could be for all business firms, a business sector like agriculture, energy, and industrial chemicals (which are said to be major contributors to carbon), the non-profit sector, or the government sector. The consolidation works only for direct Scope 1 emissions under Greenhouse Gas (GHG) Protocols, those for which a given entity is directly responsible. Including Scope 2 and 3 for upstream and downstream emissions in the consolidation would involve double counting.

Carbon statement analysis. Recognized, meaningful subtotals within the carbon financial statements can be compared to each other in a (ratio) analysis that extracts information, much like financial statement analysis. The Carbon Statement Analysis section elaborates.

To appreciate the accounting, it is important to grasp the perspective. To repeat, this is accounting for society at large. It (us!) has an equity interest in entity's CO₂ generation and reduction activities for society (we) will have to deal with the consequences (or suffer). Accordingly, assets are the entity's potential contribution to reducing carbon for our benefit just as assets in financial accounting produce potential benefits for shareholders. Liabilities are our obligation to reduce carbon because of the entity's activities just as liabilities in financial accounting are obligations of the shareholders. The net number, assets minus liabilities is our net position in carbon. However,

the entity can reduce carbon itself (and the reported liability) and that, net of emissions, is recorded in an “income statement.” With the close to book value, that changes our CO₂ position in the entity. In short, this is an accounting for an entity’s CO₂ in a society’s interest. It is a responsibility accounting for, just as shareholders in a corporation, society can intervene in its interest.

Comparison with Other Carbon Accounting Systems

The accounting here complements the E-liability accounting in Kaplan and Ramanna (2021) and the enhancement in Reichelstein (2023).⁶ That accounting conveys the carbon content in products, the so-called product carbon footprints (PCF). E-liabilities accumulate carbon along the production chain, cradle-to-gate, informing both final consumers and business-to-business customers along the supply chain of the amount of carbon emissions involved in the products they buy, and a check on claims that a product is low-carbon. Reichelstein (2023) adds a quasi-cost accounting system whereby carbon emissions in firm’s assets are accumulated and then “absorbed” into products as they go out the gate, much like the accounting for cost of goods sold in financial accounting. Rather than an adaptation of cost accounting to report carbon in products from many entities along the supply chain, the accounting here is framed in standard financial accounting terms to report a specific entity’s contribution of CO₂ to society and its efforts to remediate it. In short, this is entity accounting rather than product accounting.

The accounting here also differs from that in Barker and Mayer (2017). That accounting recognizes that both financial sustainability and the sustainability of natural resources are relevant to the board notion of “sustainability,” so incorporates an accounting for the sustainability of natural resources into the financial accounting system for reporting to shareholders. The “externalities” from the effect of operations on natural resources are charged against shareholder profit in the income statement and sustainability adjustments to assets and liabilities modify the balance sheet. With the degrading of natural resources incorporated, the notion of sustainability is modified from that provided by profits. In contrast, the accounting for carbon here is done in a separate book from financial accounting and with a different stakeholder in mind. Varying interests

⁶ The accounting in these papers is explained in *Accounting in a Sustainable World Quarterly*, Volume 1, Issue 1 (November 2022), p. 71 at <https://online.fliphtml5.com/jdbmp/bjni/#p=1> and in Volume 2, Issue 2 (March 2024), p. 58 at <https://online.fliphtml5.com/jdbmp/wsoj/#p=1>.

are thus kept separate. But the format is such that the carbon book for an entity can be compared to its financial accounting book to bring insights into trade-offs in reducing carbon.

Roston, Seiger, and Heller (2023) design an accounting system with both assets and liabilities. Liabilities are those an entity recognizes from CO₂ emissions along the supply chain, as in the E-liability accounting of Kaplan and Ramanna (2021). E-assets are investments in a trust, an agent, with carbon reducing technologies (though the agent presumably could be within the same firm). E-asset mitigates against the liability, much like an investment in a pension fund defeases a pension liability. Rather than a reporting system, the accounting is nominated as an emissions management system because it induces the entity to fund emission reduction to achieve an asset-liability match. However, with assets in dollar funding and liabilities in CO₂, the asset-liability mismatch is difficult to interpret, and there no measurable income statement to explain changes in the mismatch. The dollar funding relative to emission liabilities gives a sense of an entity's efforts in remission but the effectiveness of the spending is left open: The emission performance of the agent in reducing carbon is not accounted for, with the possibility of form over substance. Nor is there a periodic re-mark for effectiveness of the dollar funding. The accounting here reports the effectiveness of the agent or the firm itself in reducing carbon, and the proportional share of the agent's balance sheet and income statement can be consolidated with the entity's own performance statements to report the entity's overall performance on its own account or through an agent.

The Carbon Financial Statements

Here is the template for the proposed carbon balance sheet and income statement. The accounting behind the statements here will be explained as the paper proceeds.

XXX Entity

Carbon Balance Sheet at December 31, 20xx

In thousands of tons of CO₂ equivalent

Initiation date January 1, 20xx

Assets		Liabilities and Equity	
Initiation assets	A ₁	Initiation liabilities	L ₁
Periodic carbon removal	A ₂	Carbon emissions	L ₂
Carbon credits purchased	A ₃	Carbon credits sold	L ₃
In-house reduction investment	A ₄	Deferred credit for reduction investment	L ₄
Avoidance asset	A ₅	Deferred credit for avoidance asset	L ₅
Out-of-house remediation investment	<u>A₆</u>	Deferred credit out-of-house reduction	<u>L₆</u>
		Total Scope 1 Liabilities	L_{S1}
		Acquired upstream Scope 2 carbon	<u>L_{S2}</u>
		Total Liabilities	L_{S2}
		Stakeholders' Equity	
		Scope 1 equity	E _{S1}
		Scope 2 equity	<u>E_{S2}</u> <u>E</u>
Total Assets	<u>A</u>	Total Liabilities and Equity	L + E

Accounting Equations for the Balance Sheet:

$$\text{Total Assets} = A_1 + A_2 + A_3 + A_4 + A_5 + A_6 = A = L + E$$

$$\text{Total Scope 1 Liabilities} = L_1 + L_2 + L_3 + L_4 + L_5 + L_6 = L_{S1}$$

$$\text{Total Liabilities} = L_{S1} + L_{S2} = L$$

$$\text{Total Stakeholders' Equity} = E_{S1} + E_{S2} = E = A - L$$

XXX Entity**Carbon Income Statement for Year Ending December 31, 20xx**

In thousands of tons of CO₂ equivalent

Carbon Credits:

Direct carbon removal from efforts this period		Z ₁
Carbon credits purchased	Y ₁	
Sale of carbon credits	<u>Y₂</u>	<u>Z₂</u>
Total carbon credits		Z ₃

Carbon Contribution:

Gross carbon emissions before reduction from investments	Y ₃	
Carbon reduction from in-house investments	X ₁	
Carbon reduction from in-house avoidance	X ₂	
Carbon reduction from out-of-house remissions	X ₃	(<u>Y₄</u>) <u>Z₄</u>
Net carbon Scope 1 contribution before remeasurements		Z ₅
Remeasurement of prior reported emissions		<u>Z₆</u>
Net Carbon Scope 1 Contribution		Z_{S1}
Scope 2 Contribution		<u>Z_{S2}</u>
Total Net Carbon Contribution		<u>Z</u>

Accounting Equations for the Income Statement:

$$\text{Total net carbon contribution} = z_{S1} + z_{S2} = Z$$

$$\text{Net carbon Scope 1 contribution before remeasurement} = z_3 - z_4 = z_5$$

$$\text{Total net carbon Scope 1 contribution} = z_3 - z_4 + z_6 = z_5 + z_6 = z_{S1}$$

$$\text{Total carbon credits} = z_1 + z_2 = z_3$$

$$\text{Net carbon credits purchased} = y_1 - y_2 = z_2$$

$$\text{Carbon reduction from investments} = x_1 + x_2 + x_3 = y_4$$

$$\text{Period's carbon emissions} = y_3 - y_4 = z_4$$

Generating the Carbon Statements

The accounting is primarily for Scope 1 emissions for which the entity is directly responsible, and which are the actual emissions that go into the atmosphere. Scope 2 emissions can be accommodated, though separated in their own statement line items so that they do not affect the Scope 1 responsibility accounting. Like Scope 2, Scope 3 emissions could be recorded (separate, outside the responsibility accounting) but the consensus view is that these are inestimable.⁷ They would be captured as Scope 1 emissions for upstream and downstream reporting entities.

Initiation

The starting point for accumulating Scope 1 emissions affects the number for subsequent accumulations in stakeholders' equity. The accounting at initiation is similar to fresh start accounting in corporate reorganizations where assets and liabilities are recorded in the initializing balance sheet at an estimate of fair value. Such estimates can be made for legacy carbon assets and liabilities, the first asset and liability items, A_1 and L_1 , in the carbon balance-sheet template. The starting date is an issue. The date of the 2015 Paris Climate Agreement? The year 2000 that opens

⁷ See Griffin and Sun (2023) for issues in estimating Scope 3 emissions.

this century when climate change became such as issue. The date a firm sets a goal for net zero? The reference point should be clearly stated, as in the template.

Estimating legacy assets and liabilities is difficult. Any number should be justified by a backward-looking pro forma developed with the carbon statement templates. Given the estimation issues, the fresh start numbers might be set to zero (with disclosure of the fact). That is appropriate if start date is that when a net-zero goal is stated, for then subsequent accumulations report progress from a “fresh start” in dealing with emissions.

Recognition

Accountants divide accounting issues into recognition—the assets and liabilities to be booked—and measurement—how recognized assets and liabilities are to be measured. It is important to repeat that a balance-sheet asset is not an asset of the entity in its own interest, rather one for the benefit of society. Liabilities for carbon are similarly interpreted.

We proceed through assets and liabilities in the balance-sheet template in order.

Periodic carbon emissions. Scope 1 carbon emissions during a period are booked as liabilities L_2 (to reduce carbon in the future) and charged to the income statement, z_4 .

Periodic carbon removal. This is carbon reduced in production in the reporting period, for example, substituting labor for renting fossil fuel machines and practicing organic farming rather than using fertilizers from a carbon intensive supply chain. It takes on the character of an asset for society and so increases stakeholders’ equity, so is booked as the carbon asset, A_2 in the balance sheet. Correspondingly, a carbon credit is recorded in the income statement, z_1 .

However, as the effect of the reduction is already in the z_4 emissions number, the z_4 number must be the emissions before the direct reduction to avoid double accounting. Alternatively, both the income statement credit, z_1 is not reported and the A_2 asset is omitted from the balance sheet (the expedient). However, that loses information on the contribution of carbon reduction on emissions.

Carbon credits purchased (typically from a registry issuing an offset certificate) are recognized as assets, A_3 with a corresponding credit to the income statement, y_1 . Carbon credits sold are recorded as a liability, L_3 , with a corresponding y_2 charge to the income statement. $A_3 - L_3$ is the entity’s net position in carbon credits and $y_1 - y_2 = z_2$ is the periodic net credit in carbon credit trading. The

sale takes on the character of a liability as the seller must reduce carbon to justify the sale of credits. Recording the liability promotes actual reduction of carbon in the atmosphere; the seller increases its net carbon deficit if it does not remove carbon from the atmosphere. With the net position in carbon trading reported in balance sheets and income statements by both buyers and seller of the credits, there is no double accounting in a consolidation of purchaser with a seller. What is left in consolidated statements is the combined effect on carbon emissions.

There is a modification if carbon credits cover more than one reporting period: The portion applicable to the current period is booked as above while that applicable to future periods is book as a liability which then is reduced and taken to the income statement in the applicable period. The reciprocal accounting applied to the seller of credits.

The sum of the carbon removed in the period and net carbon credits, $z_1 + z_2 = z_3$ minus emissions, z_4 is the entity's net carbon emissions for the period, z_5 .

Periodic carbon removal in the period is from activities in the current period that reduce carbon. Investments are also made to reduce carbon in the future. In broad outline, the accounting recognizes these as assets but with no immediate effect on the income statement because the effect of these investments has not been realized. This parallels the financial accounting principle of recording investments as assets but not recognizing the income from those assets until it is realized. In recognizing the asset, a corresponding liability is recognized, thus with no effect on the income statement nor on stakeholders' equity. The liability reports the obligation to reduce carbon in the future with the investment technology. Income statement recognition follows on actual realization, with a corresponding reduction in the liability; the obligation had been satisfied.

In-house investment to reduce future omissions. Examples are investment in carbon capture technology and permanent sequestration of carbon, developing alternative sources of fuel with biomass technology and synthetic eFuels for aircraft, and investing in a team under a sustainability officer to deal with emissions. The investment substitutes for purchases of carbon offsets from other entities reducing carbon. Those market purchases are booked as an asset with a corresponding income statement credit in the carbon accounting, but the anticipated carbon reduction from in-house investment cannot be immediately booked as an income-statement credit because that would involve double counting; the effect would be recorded in the income statement

immediately but also in subsequent reduced net carbon. There should be no difference in reported net emissions between a firm that buys credits in the futures market (with an investment in a carbon-reducing asset) and one that does so in the spot market (with purchases of carbon offsets).

One option would be to ignore investment in carbon reduction and wait for realization in carbon emissions in future periods to recognize its effect (thus with no balance-sheet recognition). However, that fails to convey the likely reduction in future carbon. Entities' efforts to reduce carbon over long term should be communicated, otherwise their efforts to do so is not acknowledged. Disclosure might remedy somewhat, but there is an accounting solution: Record an asset, A_4 and an offsetting liability, L_4 for the expected carbon reduction over the estimated effective life of the investment. The asset communicates the prospective carbon reduction and, with an equal amount recognized as a liability to remove carbon in the future, there is no effect on stakeholders' equity that reports the accumulated carbon position to date. The liability is similar to a deferred revenue account in financial reporting when revenue is unrealized, and it is labelled as a deferred credit in the template. When the effect of the reduction is realized in each future period, both the asset and liability are reduced with no effect on the income statement; the asset is effectively amortized against the deferred credit.

However, the amount of actual periodic reduction of the asset and liability from in-house investment can be communicated in the income statement by grossing up the carbon emissions number, z_4 by the amount of the realized effect, x_1 in the template. This is number by which the deferred credit liability (and asset) are reduced each period. The gross-up number is an estimate of what the actual emissions would have been without the investment relative to the emission achieved. That reports the ex-post success of the investment in carbon reduction. As a gross-up of that emissions number, there is no effect on the actual number for carbon emissions, z_4 (and no double counting). The grossing up is just communicating the periodic benefit of investing in carbon reduction, adding information.

Further information can be provided by dividing the gross-up number into the emission reduction expected and actual reduction achieved relative to the expected reduction. The conveys information about the success (or otherwise) in making remission investments and for booking in-house investment assets and liabilities with estimates in the future. It also promotes a

(cancelling) remarking of the A_4 and L_4 carrying values in the balance sheet, including impairments if actual is lower than expectation.

Avoidance investments, for example, a forest set for logging by the entity is now preserved for carbon capture, or clean-energy technology is substituted for fossil-fuel technology. This investment differs from in-house investment as it does not necessarily require cash investment; the investment is in the form of an opportunity cost. As with in-house investments, an asset, A_5 for the estimated future remission is recorded along with an offsetting deferred credit liability, L_5 . The income statement accounting then proceeds with the same accounting as for in-house investments. x_2 is recognized as another gross-up from the actual carbon emissions.

Correspondingly, cutting down a forest that absorbs carbon is treated as a contra A_5 asset and reduces the deferred credit, L_5 to be recognized in the income statement later. Potentially, both the A_5 asset and L_5 liability could be negative with the consequent negative effect on the income statement reporting the increased emissions for which the entity is responsible.

Out-of-house investment, for example buying land in the Amazon rainforest that has been deforested and restoring it to absorb carbon. This will not show up as remediation unless booked. So, record as an asset, A_6 with an offsetting liability, L_6 , as with in-house investments. The asset conveys future carbon reduction but is also a carbon asset that can be traded. The deferred credit liability is periodically reduced by the amount of periodic carbon capture from the emerging rainforest with a gross-up credit to the income statement, x_3 for the effect, as in the template. The amortization period is to the maturity of the rain forest at which point the forest (presumably) is no longer is a net absorber of carbon.

The total from realizing the effects of these investments each period, $x_1 + x_2 + x_4 = y_4$ is added to the direct carbon emissions, y_3 to report z_4 , the entity's carbon contribution to the atmosphere in the period before the effect of direct reduction. Thus $z_3 - z_4 = z_5$ yields the net Scope 1 carbon contribution for the period. The line items in the income statement can be reduced by combining the effects of in-house investment, avoidance, and out-of-house investments. However, the template here recognizes that there might be some information in distinguishing the different types of remediation in the entity's strategy which can be important in pro forma strategy analysis (to be introduced later). Also, as estimation is required, the quality of the estimates might differ over the alternative remediation efforts.

The realization principle. Financial accounting principles require realization of revenues before they can be booked, with the complimentary principle that expenses be actually incurred. That applies to carbon accounting also. Actual carbon emissions are not booked until they occur but also carbon remediation: Anticipated carbon reduction from investments are not recognized in the income statement, but as assets, going to the income statement only when they are realized.

Derecognition. Assets and liabilities from in-house investment, avoidance investment, and out-of-house investments decline (by the equal amounts) as the effect of the investment is recognized in the income statement. However, the asset for direct carbon reduction, A_2 builds up over time, as does the liability, L_2 (with no effect on equity). This is appropriate if the contribution to net carbon from the initiation date is to be communicated. However, after some period when part of the history becomes (informatively) stale, that portion of the asset can be derecognized against the emissions liability. This might be at the date set in a zero-carbon goal.

Discounting. Society is presumably impatient in getting carbon removed from the atmosphere. Thus a strategy for reducing carbon emissions that has an effect in the near future is viewed differently from one with an effect in the distant future. Assets and liabilities recognized for latter then might then be discounted. The discount rate, in principle, would be at the cost to society of the delay but that would be hard to the measure. In absence of a market that trades long-term remission technology for short-term remission technology (effectively priced), the risk-free rate (society's impatience for consumption) is an objective measure. A risk premium might be added for the risk that the entity might not survive to deliver the benefits from the investments. Both assets and liabilities grow at the discount rate by the same amount as the future comes closer, so there is no effect on the income statement. That is similar to the income statement effect in financial accounting where a firm issues debt at a given discount from face value but holds an equivalent amount of debt at the same discount rate as an asset: The income statement effect nets to zero.

Measurement

Ideally, the unit of measurement would be the price society places on a ton of emitted CO₂. Carbon trading markets do exist but there is much skepticism about the prices set. So, measurement is in equivalent units of CO₂. Many jurisdictions, including those in the U.S and EU provide guidance on CO₂ measurement and verification as do sustainability standards boards. The measures must be

the same as that in stated goals and milestones, and consistently applied. Cross-sectionally, they should be comparable, apples-to-apples.⁸

The integrity of the reporting depends on confidence in the measures, and the difficulties of measurement in this arena are well known. Carbon credits are often seen as suspect in terms of the actual CO₂ reduction they actually buy. Certified forest credits are viewed skeptically. Several estimates of assets and liabilities are made in the accounting here and some income statement numbers require estimates of periodic effects of in-house, avoidance, and out-of-house investments. These must be evidence-based. The application of the realization principle for the net number after these estimates reassures.⁹ Further, the reporting of the realized effect of assets in subsequent income statements checks the assets estimates against actual. Auditing and enforcement further assures. In the case of carbon credits, that might be supplied by the registry for carbon credits as with a clearing house. The entity's own carbon reduction asset estimates can similarly be audited.¹⁰

Financial accounting principles in the FASB and IASB Conceptual Framework disqualify the booking of assets and liabilities when there is high measurement uncertainty, and specific accounting standards recognize assets and liabilities only when the item is probable and estimable with relatively low measurement uncertainty. If that is so with carbon accounting, the informativeness of the estimated in-house, avoidance, and out-of-house assets and liabilities in the balance sheet and the gross-up numbers in the income statement come into question, requiring supporting disclosure.

The quality of carbon measures appears to be improving over time. The Voluntary Carbon Markets Integrity Initiative, launched with backing from the British government, sets guidelines to deter vacuous claims about the benefits of offsetting. The Integrity Council for the Voluntary Carbon Market, a successor of Mark Carney's Taskforce on Scaling Voluntary

⁸ Jia, Chaudhury, and Ranger (2023) point out comparability issues with GHG emission metrics.

⁹ Kaplan, Ramanna, and Roston (2023) invoke the realization principle in recognizing carbon offsets and add other measurement principles that can be applied in the accounting here.

¹⁰ There is a difficulty in auditing, as recognized in Letmathe (2024): The auditor who is not immediately at the point of emissions, has difficulty in attesting to the verifying amounts of reported emissions later. The solution offered in that paper is to benchmark reported emissions against inherent emissions, that is, emissions embedded in materials used in production processes that are released during the process.

Carbon Markets announced a set of “Core Carbon Principles” to assess the quality of existing schemes. Non-profits like Carbon Market Watch serve as monitors. However, wider standards (including auditing standards) are called for to deal with estimation and potential gaming of the measures.¹¹

Quality scoring

Considering these issues, the reporting can be accompanied by a quality score, the ratio of “hard” numbers to “soft” numbers subject to estimates, much like a quality score in financial accounting compares accruals subject to estimates to “hard” cash. So, if avoidance assets are difficult to estimate, the ratio of those assets to total assets indicates the uncertainty about the asset numbers. In the income statement, any element in y_4 or the total y_4 can be compared to a relatively “hard” emissions number, z_4 .

Layering and collapsing the accounting

The proposed accounting can be viewed in terms of the relevance versus reliability tension in financial accounting: The accounting identifies relevant elements subject to the reliability of their measurement. The reliability criterion raises the prospect of either discounting asset amounts (a haircut) or collapsing the accounting if estimates are deemed too imprecise. The latter can be done by reversing the orderly construction of the accounting above. The accounting has been presented as a successive layering of components of assets and liabilities and corresponding numbers totaling to net emissions in the income statement, and the order is judged to be by in degree of the quality of the estimates. Call initiating assets and liabilities, A_1 and L_1 level 1 of the layering to which the relatively hard assets and liabilities for current emission and direct reductions, A_2 and L_2 are first added in level 2. Then the level 3 for carbon credits purchased and sold, then the level 4, 5, and 6 investment assets and liabilities where estimation issues arise. Admittedly this might not be the correct ordering in terms of estimation error, but the balance-sheet presentation can be changed with a layering that aligns with the quality of the estimations for a given entity. That, along with quality scoring, informs the user about confidence in the numbers, along with reference to footnotes for embellishments.

¹¹ An example is the CX-0029 Product Carbon Footprint Rule Book for the automobile industry. See Catena-X (2023). Tfs (Together for Sustainability) provides guidelines for measuring PCF in the chemical industry.

The user might have such low confidence in some numbers so as to strip them out. Carbon reduction from avoidance assets, for example, are seen as particularly difficult to measure, relying as it does on counter factials. That amounts to a collapsing of the layering to get back to relatively hard numbers. So, for example, the level 5 and 6 assets and liabilities for avoidance and out-of-house remissions might be deleted as would the x_3 gross-up number in the income statement. If the total gross-up for direct emissions, y_3 is also deemed to be a fuzzy number, it disappears, as do all gross-up numbers to get to that number. In the extreme, with concerns about all the carbon trading numbers, only A_2 and L_2 assets and liabilities remain on the balance sheet and only net direct carbon emissions in the income statement. The accounting collapses to the flow number currently reported.

The consequent loss of information is clear. The quantification for aggregation over time, responsibility reporting, asset and liability reporting, strategy formation, incentives, pro forma analysis, consolidation accounting, and carbon analysis disappears. Further, as the balance-sheet numbers must settle up against reliable realized emissions, requiring the accounting also requires integrity in measuring the actual emissions flow number provided currently (about which there are complaints). This reinforces the need to develop standards for credible measurements with verification mechanisms. The financial reporting system contains many estimates, but these are subject to controls, governance oversight, audit, and regulatory sanctions, and thus are typically relied upon.

Estimates are subject to change so re-marking estimated assets might be warranted. For (estimated) in-house, avoidance, and out-of-house investment assets, that is done with a remarking of the corresponding liability. So, for example, if the estimated carbon capture from an out-of-house reforestation project changes, A_6 is modified along with L_6 , again with no effect on the income statement or equity. As measurement becomes more precise over time, the number for prior realized emissions, z_4 might need remeasuring. So the income statement template reports a line for remeasurement. This reporting is a check on bias in reporting realized emissions: The bias is later disclosed. The volatility of this number also gives an indication of the difficulties with measurement. This is a one-time item necessary to correct the accumulated net contribution, so the preceding line in the income statement gives the current period's carbon contribution.

The income statement is completed with Scope 2 emissions from upstream (suppliers). While added to the income statement as z_{S2} and tracked separately as E_2 in stakeholders' equity, these are not part of the accounting for the entity's contribution to atmospheric CO₂, nor are they included in consolidations. However, the Scope 2 number serves as a check against gaming the Scope 1 number. An entity that shuts down its polluting power plant and buys power from the upstream, reduces its Scope 1 number but increases its Scope 2 number. Further, reporting the Scope 2 number gives an incentive for the entity to put pressure on its suppliers to reduce emissions in supplying electricity, steam, heat, and cooling. While only the S2 carve out from upstream S3 emissions is included here, it potentially could include all upstream S3 emissions though identifying and measuring them from "cradle" to entry "gate" is presumably a tall task.

Transactions

Some examples have been sprinkled throughout the text to this point. Here is more of how selective transactions or events are recorded:

- Monitors measure the periodic emissions from a plant. The CO₂ equivalent is recorded as a z_4 emission in the income statement with a corresponding L_2 liability. The liability is an obligation to remove the emitted CO₂ for the benefit of society.
- A firm invests in equipment to capture carbon from a chimney, with an estimate of 20 years for the useful life of the equipment. The technology is estimated to capture and sequester 80% of carbon emitted. With an estimate of carbon that would otherwise be emitted, the total estimated reduction over the 20 years is booked as an in-house asset, A_4 , discounted for time, with an offsetting deferred credit liability, L_4 also recorded such that the income statement and equity are not affected—the emission effect had not been realized. The asset reports the entity's efforts to reduce carbon in the future that is not conveyed by the current z_4 number. As time proceeds, A_4 and L_4 are reduced by the realized periodic reduction in CO₂ from the technology that results in a lower z_4 number, with a grossing up with the x_1 number in the income statement to convey the contribution from investing in the technology. A_4 and L_4 are revised when the estimate of the effect of the technology changes, promoted by differences in actual versus estimated effects.
- A firm purchases carbon credits in a carbon market. Provided the amount of CO₂ in the offsets is validated, the license to emit carbon is recorded as an asset, A_3 . A corresponding

credit to the income statement, y_1 is recorded, to be netted against carbon emissions for those periods.

- A firm removing carbon from the atmosphere (with direct capture, biomass technology, or enhanced weathering of rocks to increase carbon absorption, for example) sells carbon credits to carbon emitters. The sale of carbon credits is recorded as a liability to reduce the carbon for the carbon credit sold, with a corresponding charge to its carbon income statement because the sale of the carbon credit gives license to the buyer to emit carbon. The seller of the credit also records carbon removed by the technology (with a corresponding A_2 asset recorded). The income statement thus foots to the net carbon removed and the balance sheet asset nets against the liability. A consolidation so buyers and sellers of the credits reports the net effect of the carbon trading. The accounting for investing in technology, as in the second case above, is added to convey the anticipated effects of a firm investing in selling carbon credits.
- A dairy farmer develops a seaweed farm to produce red seaweed as a supplement to cow feed to reduce methane emissions. That is an in-house investment, A_4 the benefits of which are recognized in future carbon income statements, x_1 . Another farmer simply buys seaweed on the spot market to feed to cows. That reduces periodic carbon emissions, z_4 but no asset is recorded.
- In 2023, with carbon credits selling as low as \$3 per ton removed, the carbon credit market fell into disrepute as a number of reports raised doubts about how much carbon was actually being removed by sellers of the credits. Corporate purchases of credits consequently declined. (Audited) carbon accounting by sellers of credits reports on the integrity of carbon removal claims.
- In early 2024, the U.S. Department of Energy announced a plan to encourage carbon capture, setting up a “leader board” to highlight companies making the biggest efforts. The carbon accounting reports on companies’ efforts with an ex post settling up. If those companies sell carbon credits, the accounting reports on their integrity in actually removing carbon as claimed.
- An on-site solar plant is installed to replace fossil fuels to generate power. This is another in-house investment. The emissions generated in building the solar plant are recorded as part of current emissions, z_4 . However, an asset for the estimated future emissions is

recorded, conveying the trade-off between current and future emissions that the plant generates.

- A firm builds a wind power plant remotely to sell power to others. Any reduction in CO₂ is not recorded in the firm's carbon accounts, to avoid double counting. That is reflected in the carbon accounts of the purchaser of the power.
- A long-term contract is signed to purchase wind power from the firm building the plant in the previous example, replacing coal power. The effect is recorded in the income statement in periods when the reduction in emissions takes place. But, being a long-term contract, an asset could be recorded for the (discounted) expected emission effects with an equal recorded (deferred credit) liability.
- A firm builds an eco-friendly building to which it moves from a less efficient building. Treat as an avoidance investment in carbon reduction with an A₅ asset and L₅ liability recorded.
- An EV manufacturer installs recharging stations along rural highways that promotes the use of EVs. An A₆ asset is recorded for estimated reduced future emissions relative to fossil-fuel vehicles, along with the corresponding L₆ liability which is then reduced and credited to the income statement as EV miles accumulate. Changes in estimates of EV use of the charging stations are A₆ and L₆ remeasurements.
- A firm rents an eco-friendly building. The periodic emission effects are recorded directly in the income statement with no asset or liability recognized.
- A firm provides emission-light busses for employees commuting to and from work. The anticipated CO₂ reduction with these busses are an in-house remission investment, A₄.
- A firm is granted an emission allowance from a government agency. This does not enter into the accounting; net emissions are still reported so that the maintained effect on society is conveyed. Footnote disclosure informs of the license.
- A firm shuts down its polluting power plant and buys power upstream from other polluting producers. That reduces its reported Scope 1 emissions but not emissions overall. However, the reporting of Scope 2 emissions mitigates; the firm reduces Scope I reported but increases Scope 2. That cuts across any gaming of the reporting.
- A firm refines fossil fuels but has no upstream oil production. In the refining process with its green technology, the firm emits little CO₂. Even though the final product involves

emissions from the use of fossil fuels, the accounting reports relatively low CO₂ generated by the firm. This illustrates the responsibility accounting under which only the emissions for which the firm is responsible are accounted for. Emissions upstream and downstream are in the accounts of other entities involved.

- A firm has a fleet of trucks, ships, or aircraft to distribute its product, with the fleet emitting carbon. It decides to outsource the distribution, thus reporting lower emissions. However, those emissions are generated by the alternative operator, so this arrangement reduces carbon overall only if the operator is more efficient in doing so. An in-house asset, A4 might be recorded for any efficiency but not the entity's total emission reduction, otherwise there is double counting.

This outsourcing of carbon emissions can be gamed to report lower emissions but with no overall emission reduction. With the alternative operator taking a penalty by reporting increase carbon emissions in its own carbon accounts, that operator presumably charges a price for the outsourcing, a financial cost to the outsourcing firm and a disincentive. Further, the alternative operator's increased emission could be recognized as an additional line item in the income statement like the Scope 2 number, perhaps titled "reduced emissions due to outsourcing emissions." Added disclosure further mitigates by informing that the responsibility for emissions has been passed on to another entity with a statement of the likely reduction on carbon emissions (if any).¹²

- An aircraft manufacturer develops a new model of aircraft that significantly reduces CO₂ emissions downstream. The consequent reduction in Scope 3 emissions is not recorded in the accounting system if it is inestimable. That is an omission in reporting the manufacturer's efforts to reduce carbon. Indeed, the firm might have to increase Scope 1 emissions in developing the new product while reducing downstream emissions. Qualitative disclosure ameliorates. If the Scope 3 emission reduction is estimable, it can be recorded on separate line items in the income statement and balance sheet, as with Scope 2 emissions.

¹² The European Commission is concerned with outsourcing of emissions outside the EU, imposing an import penalty on goods in carbon-intensive industries.

If readers see transactions that cannot be accommodated in the proposed accounting, the author would appreciate hearing from them.

Analysis with Carbon Statements

Financial statement analysis combines line items in financial statements (typically in ratios) to extract information that line items jointly convey. So do carbon statements. But there is an additional feature: With financial statements published in conjunction with carbon statements, additional insights emerge by comparing the carbon statement information to financial statement information.

Carbon Statement Analysis

Rate of return from carbon remediation = $z_{5,t}/E_{S1,t-1}$: Periodic net carbon contribution relative to the absolute value of accumulated carbon contribution in stakeholders' equity at the beginning of the period. This measure, corresponding to the rate of return on equity in financial statements, is the rate at which the entity is reducing carbon. A negative ratio indicates expansion of an accumulated deficit or a decrease in a surplus. A positive number indicates an increase in the accumulated surplus or a decrease in deficit. The time series of the ratio indicates the speed of remediation. That projects the probability of reaching net zero accumulations by a target date. The speed of remediation is comparable in the cross-section though not the measure itself if entities have different initiation dates.

Net carbon contribution relative to milestones. This compares the carbon for a period to a milestone set as a goal. It can be for the flow measure, z_4 in the income statement or the stock measure, accumulated carbon in equity on the balance sheet. Or it can be calculated for the two combined. The comparison, a variance from estimated, promotes a rethinking of the estimate or the carbon-reduction strategy.

Carbon generated relative to carbon remediated = z_4/y_4 . This income-statement measure compares gross carbon emissions (before reductions from in-house, out-of-house, and avoidance investments) to the sum of total carbon credits and carbon reductions from in-house, out-of-house, and avoidance investments. It reports the relative contribution of emissions and remediation to the bottom-line income statement number.

Net carbon credits purchased relative to direct carbon emissions = z_2/z_4 . With z_2 the net carbon credits purchased equal to credits purchased minus credits sold, this measure indicates the extent to which carbon emissions are from license from carbon trading.

Carbon assets relative to stakeholders' equity = A/E . Similar to an assets/equity ratio in financial accounting, this conveys the amount of carbon assets relative to the equity deficit (or surplus) and can also be calculated as L/E as with a debt/equity ratio.

Deferred Credit Liabilities to Carbon Emission Liability = $(L_3 + L_4 + L_5)/L_2$. This the extent to which the deferred credit liabilities to reduce future carbon compare to the liability for carbon reduction from current and past direct carbon emissions.

Liabilities for future carbon reduction to current carbon emissions = $(L_3 + L_4 + L_5)/z_4$. Conveys the expected future carbon reduction relative to current emissions.

Deferred credit decline. Measured as the reduction of deferred credits for in-house, avoidance, and out-of-house carbon investments relative to the beginning-of-period deferred credits. This reports the speed at which deferred credits from carbon investment are being used up.

Comparative Carbon Statement Analysis and Financial Statement Analysis

Society creates entities for specified benefits with the side effect that those entities produce carbon. So a comparison of carbon metrics to those benefits puts the carbon output in perspective: net carbon is evaluated with a trade-off off against the benefits the entity provides, widening the evaluation to “sustainability” more generally. For non-profits and governments, the benefits are likely subjective, non-measurable, so the analysis is confined to business firms where financial reporting accounts for benefits with profits added to shareholders' equity but also the return to labor and debt capital. That said, consolidation of carbon statements of all entities at the national level can report aggregate net carbon produced relative to the common well-off measure, GDP. Indeed, such a comparison confronts the criticism of GDP accounting that it does not recognize the cost to society of carbon emissions in generating GDP. And, for non-profits, an investor might wish to leave wealth to a charity but is concerned with how that charity emits carbon so weighs net carbon emitted against the perceived benefits of the charity's endeavors.

For a business firm, investors and employees seek wealth but are also concerned about the quality of the air and carbon effects on climate. The comparison is particularly pertinent with the current

trend to sustainable investing where the investor is choosing investments with a sustainable profile: How much carbon is the firm producing relative to benefits? A firm reducing carbon emissions while adding profits from attracting customers who desire green products is to be distinguished from one that adds profits while increasing net carbon emissions.

The metrics that follow are neutral as to moral and ethical considerations though under regulation there could be legal ones. Those questions are left to the investor and society more generally.

Periodic net carbon relative to periodic operating profit. This compares the bottom line in the carbon income statement to that in the financial income statement, possibly with an averaging over a few prior years. It answers the question: To what extent is the investor's wealth creation at the cost of producing carbon? Or, to what extent is the carbon produced compensated by added wealth?

The comparison identifies an eco-resort that invests to maintain forest and habitat but fails to attract tourist revenue. Both the business and the carbon reduction effort are unsustainable. Eco-tourism that both reduces carbon and attracts revenues yields enhanced benefits to society. For other firms, carbon reduction might be a cost that reduces profits, but the firms also create consumer products from removed carbon, like personal care products or food additives that might add to profits. As could using carbon as a reagent in mining and metallurgical processes. And removing carbon could increase sales and profits for firms from consumers seeking "green" products. Thus, while the comparison of reduction to carbon reduction costs provides information, comparison to total operating profits includes these and other secondary effects. With concern about the future, the asset accounting allows the investor to compare the expected future net carbon along a path to future forecasted income.

The metric responds to the requirement under the IFRS S1 and S2 standards to identify sustainability-related risks and opportunities and their effects on firms' cash flows. The measure can be calculated at a consolidated level, for an industrial sector for example. For investment funds advertising sustainable investing, the reporting is on a consolidated basis over the fund's holdings. At the national level consolidated net carbon is relative to GDP.

Periodic net carbon relative to periodic total return to capital and labor. Financial statements (with added detail) report returns to debt capital and returns to labor (including fringe and pension benefits) as well as returns to shareholder capital. The calculation for shareholders in the previous

metric can also be made for these beneficiaries of business activity. An employee, for example, might be interested in the sustainability of promised pension benefits given the reported projection of CO₂ production and remediation and in the tradeoff of wealth in retirement and healthy air during retirement.

Periodic net carbon relative to sales revenue. This measure is like a profit margin: What is the net carbon (profit or loss) relative to sales? It informs about the amount of net carbon contribution to society relative to the market value of products that society demands and buys. (With any growth in inventory out of steady state there is an adjustment for carbon in inventory). It is a measure of carbon intensity required under ESRS E1 disclosure. Bolton and Kacperczyk (2021) report that institutional investors screen firms on this metric. With the carbon accounting, both stocks and flow measures can be applied.

Carbon reduction from in-house carbon investments relative to depreciation of those investments. The periodic reduction from investment in carbon reducing technology (reported in the carbon income statement) is compared with the annual cost of the investment given by depreciation for the period. This reports the economic efficiency in reducing carbon which can be compared across alternative technologies and also in proforma.

Avoidance benefits relative to avoidance cost. With in-house avoidance of carbon—the example of preserving a forest for carbon capture rather than logging—a period’s carbon reduction in the income statement template is compared to the loss of profits or profits plus labor income (from logging).

Net contribution relative to a carbon tax. Provided carbon taxes are disclosed in financial reports, the measure conveys the amount of the tax relative to the amount of net carbon emissions for comparison across firms and across time.

Carbon emissions measures are typically interpreted as damage metrics. The comparison of carbon measures to financial reporting metrics gives a sense of relative damage. But that is only from the point of view of constituent interests in firms. Clearly, the relative measures are not a measure of social value.

Pro Forma Statements

The financial reporting system is often applied to develop pro forma statements for the future. That is sometimes done for just one feature in the statements, for example with earnings forecasts, though that is implicitly done with a pro forma of the line items in the full income statement. These proformas are for expected values, as with point estimates for earnings forecasts, or with outcomes modelled under alternative scenarios to provide a picture of possible variation around expected values.

Pro forma carbon statements. Parallel carbon accounting also lends itself to pro forms analysis. Such analysis is pertinent where an entity states a (net-zero) carbon goal by some date. Pro forma statements model the future line items by which the goal will be achieved. The preparation of such statement disciplines management in stating the goals. The statements, with alternative scenarios modelled, are an input for selecting a carbon strategy and its execution. And pro forms statements are the benchmark for evaluating a strategy ex post, budget versus actual: Did the strategy work? Does it require modification?

Comparative proforma analysis. A comparison of proforma carbon financial statements with proforma financial statements informs corporate strategy. What will be the effect of a given strategy on carbon remediation relative to corporate profits? What is the best strategy? That calculation is also relevant to government oversight: If remediation benefits are unfavorable relative to loss of profits for firms, regulation, subsidies, or government investment might be advocated but now with greater transparency as to payoffs. In July 2023, the U.K. government proposed four carbon capture and storage projects, seeking investors to support them. Some analysts were forecasting a \$600 billion industry in this technology. Will net zero goals be achieved and at what cost?

Consolidation Accounting and Aggregation

Society has interest in the carbon emissions at the entity level but also in the aggregation of like entities, So, while the agricultural sector is said to be a large carbon emitter, it is also a sector necessarily for human survival. How much net carbon does it produce and what is the path to carbon reduction while maintaining food production?

Consolidation accounting combines the accounts of entities in a group, most commonly to account for a holding company and its subsidiaries as one economic unit in which shareholders

have an interest. Simply, assets, liabilities, revenues, and expenses for entities in the group are aggregated with any intercompany transactions eliminated to avoid double counting. The proposed carbon accounting lends itself to this aggregation though, with the accounting for individual entities in the group limited to their Scope 1 emissions, no eliminations are necessary. As with the accounting for individual entities, the consolidated aggregate reports the income-statement total flow number for the group with the gross-up reporting the periodic reduction in emissions from assets generated by prior investments in reducing carbon. And the consolidated balance sheet reports those assets and the liabilities that net to the accumulated deficit or surplus in stakeholders' equity.

The aggregation applies to any designated group: the for-profit sector, the not-for-profit sector, industries, countries, and governments. Aggregating over all groups in a country reports the totals in contributing to its government's promises under international protocols and treaties. Within an entity, disaggregation reports the contribution of sub-entities such as divisions of business firms or government departments like the defense department. Thus there is an accounting of where society's carbon is being generated and where remediation is taking place. Further, with consolidation a group's net contribution can be evaluated in terms of its effect on the aggregate. So, for example, miners of necessary minerals for the manufacture of lithium batteries for carbon-reducing EVs might be viewed differently from identified "polluters," as might the net carbon reported by the defense department.

For investors investing in an ESG investment fund, the aggregate for investment holdings in the fund can be reported as an input into ESG fund ratings that, at present, are often viewed skeptically. That aggregate can be compared with the (financial) returns the fund generates.

Conclusion and Limitations

The accounting here does not capture downstream Scope 3 emissions by consumers of a firm's product. So, if a firm changes its production technology to reduce the carbon that will be emitted with the consumption of the product, that is not accounted for. Redesign of airplanes and automobiles are examples. That change in technology could even result in higher reported Scope 1 emissions while reducing overall Scope 1 and Scope 3 emissions. Scope 3 emissions are omitted because the focus is on emissions for which the entity is directly responsible and because the number is deemed inestimable. If estimable, Scope 3 emissions could be included like the Scope

2 emissions in the templates, but clearly separated from the Scope 1 number that can go into a consolidation.¹³

The same applies to upstream Scope 3 emissions, with the omission compounding the omission of downstream Scope 3. So, a firm might reduce downstream Scope 3 emissions by changing its production methods but, in so doing, increase upstream emissions (from the mining and production of lithium, for example). Disclosure possibility ameliorates.

Scope 3 emissions are Scope 1 emissions of other entities, so can be accounted for in a report to society by those entities. However, it is hard to see downstream consumers generating formal carbon accounts. Mandated reporting (in tax returns, for example) is unlikely. Thus aggregation of Scope 1 emissions through consolidation of reporting entities will not yield the comprehensive aggregate at a society level.

These points aside, the proposed accounting is a responsibility reporting on carbon emissions that not only reports periodic emissions in a quasi-income statement but also an entity's accumulated position in carbon in a balance sheet. Assets net of liabilities explain that accumulated position and, in so doing, the balance sheet reports assets that bear on the future reduction of carbon by the entity. Thus, an entity is evaluated not only on current CO₂ emissions but also on its efforts to reduce future CO₂ emissions. A balance sheet and income statement also enhance the responsibility reporting by governing pro forma accounting for modeling the effects of strategies to meet stated net-zero goals, with the pro forma targets providing the benchmarks to which subsequent realized income statements and balance sheets can be compared to evaluate the success of those strategies, prompting their revision. The carbon accounts can be aggregated across entities in a consolidation accounting that reports the position of groups such as industries and government agencies. In the form of financial reporting, the carbon statements can be compared to financial reports to evaluate financial and carbon reduction tradeoffs and to address the issue of "sustainability" more generally.

¹³ Kaplan and Ramanna (2024) conclude that downstream emissions should be disclosed rather than accounted for and provide guidance on how that might be done, including limitations.

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