What is Greenhouse Gas Accounting?

Turning Away from LCA

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ghg management institute

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Forward

This installment can be considered equivalent to a movie prequel that provides the "backstory" for the other installments. It is therefore fine to read this installment first and then proceed to the others.

- What is Greenhouse Gas Accounting? Furnishing definitions (Installment N.1)
- What is Greenhouse Gas Accounting? Fitting to purposes (Installment N.2)
- What is Greenhouse Gas Accounting? Allocation rules (Installment N.3)
- What is Greenhouse Gas Accounting? Further Thoughts on Responsibility & Causation (Installment N.3 bis)

Next to come in this series is an installment addressing the role of market-based approaches to GHG accounting.

1 Introduction

There has never been a time in which corporate environmental disclosures, and specifically corporate greenhouse gas (GHG) emissions reports, have been given more attention.[1,2] Underlying this attention are muddled debates involving the concept of and rules for "GHG accounting".[3] Sadly, despite the two plus decades of guidance and standards work on corporate GHG reporting, technically rigorous definitions describing discrete forms of GHG accounting are lacking (Ascui, 2014). The result is a confusing mismatch of intended purposes of corporate GHG accounting metrics and accounting rules. Underlying these problems is the current approach to corporate GHG reporting that assumes a single generalizable protocol (e.g., the GHG Protocol's corporate standard) can address all purposes. Instead, I will show that this current approach is neither fit for most purposes nor, as currently structured, should it be deemed proper GHG accounting. Despite this current state of affairs, effective reform in our approach to GHG accounting that moves us to more useful and reliable GHG reporting is possible.[4] Such reforms, though, will vary by the purpose for which the GHG accounting is performed.

The GHG Protocol corporate standard was first published in 2001 and revised in 2004 by the World Resource Institute (WRI) and the World Business Council for Sustainable Development (WBCSD). It effectively created the practice of estimating and reporting GHG emissions and removals at an organizational scale (Sundin and Ranganathan, J, 2002; WRI/WBCSD, 2004). Although since then numerous other standards and programs have emerged that address corporate GHG reporting, they all largely or entirely defer their accounting rules to the GHG Protocol (Jia et al., 2023, 2022). The GHG Protocol corporate standard is an artifact of its time. In the early 2000's the USA was withdrawing from the Kyoto Protocol, and national government policy and intergovernmental action were seen as failing to adequately address climate change. During this period environmental issue groups turned their attention to voluntary action by businesses and local governments. The overarching objective of introducing corporate GHG reporting and target setting initiatives was to shift expectations of businesses to recognize climate change and for leading companies to become allies in building the norm for climate action. The goal of these initiatives was simply that companies add GHG emissions to their internal management concerns by examining where "their" GHG emissions were coming from and to introduce some accountability through external reporting. The expectation was that eventually this added attention would have beneficial environmental and political effects of curtailing emissions and

[1] For example, there are various new mandatory reporting requirements emerging such as new rules under the U.S. Securities & Exchange Commission (U.S. SEC, 2023), California's Climate Corporate Data Accountability Act (SB 253), EU Corporate Sustainability Reporting Directive (CSRD) (European Commission, 2022), United Nations initiatives to engage non-state actors (UN HLEG, 2022), as well the expanding trend of companies making "net zero" pledges (Frederic Hans and Takeshi Kuramochi, 2022).

[2] I will use the term "emissions" throughout this paper for the sake of brevity, but readers should interpret this as a shorthand for GHG emissions and removals.

[3] There is a sound argument that referring to the technical process of quantifying GHG emissions and avoided emissions should not be referred to as "accounting" given the association of the term with financial matters. I am highly sympathetic to this argument but lack a superior alternative term that differentiates the generic act of quantification from the more precise practice of producing an environmental data time series as defined in this paper. As financial accounting records monetary transactions, one could crudely view GHG accounting as recording human transactions of GHGs with the atmosphere.

[4] I will regularly refer to companies as the subject of discussion for convenience, but the reader should recognize that the discussion in this paper is intended to be applicable to organizational entities more broadly, and often to any subject on which GHG accounting is performed (e.g., countries, facilities, companies, products, cities, projects, policies).

addressing the risks of climate change.[5] But, the technical quality or meaning of corporate GHG reporting was given little attention so long as companies completed the exercise. In return, they received a new way to burnish their business reputations as an environmental leader (Condon, 2023; Green, 2010; Patchell, 2018; Walenta, 2021).

But, since the early 2000's, expectations have changed. Twenty years later, government regulators, investors, and other actors are proposing to formally use reported corporate GHG emissions data for specific decision-making functions that go beyond informing internal corporate management. In response, GHG accounting concepts and rules need to mature in keeping with the technical requirements for specific applications of corporate GHG metrics. For example, the existing GHG Protocol corporate standard and its derivatives give enormous flexibility to companies in setting their accounting boundaries. The underlying assumption was that in a voluntary reporting context, where results are simply used to inform internal management considerations, reporting should not require oversight or enforced coordination. Each company's GHG inventory report, as a result, has effectively been bespoke.

I will argue that the root of the problems with current corporate GHG accounting practices derives from its underlying conceptual framework, which is the assumption that one can produce a meaningful GHG accounting metric through a form of life-cycle assessment (LCA) on an entire organization.[6] Rules and concepts developed for use in product LCA were adapted by the GHG Protocol for application to companies, albeit addressing only GHG emissions versus multiple environmental burdens (Ekvall, 2020). For example, similar to the aggregation of emissions released at every life cycle stage of a product, current corporate GHG accounting attempts to aggregate all emissions released at every process occurring within a company's value chain. Yet, product LCA itself has struggled to find practical applications and adapting its methods to analyze entire organizations that are far more complex than single products, only amplifies its problems. I will further argue that constructing corporate GHG accounting rules using LCA thinking was a conceptual error and has led to a lack of meaningful and useful corporate GHG reporting, especially with respect to indirect emissions (i.e., GHG Protocol Scopes 2 & 3). Specifically, current corporate GHG emission inventory practices result in reports that are not comparable across companies (i.e., subjects), do not produce a meaningfully consistent time series for individual subjects, have subjective and ambiguous spatial and temporal boundaries, involve rampant duplicative counting of emission sources by multiple subjects, and improperly apply consequential justifications within an allocational environmental accounting framework (Downie and Stubbs, 2012; Gillenwater, 2022; Klaaßen and Stoll, 2021). Whether or not these problems matter depends on the precise purpose for which a GHG metric is to be used. It may be true that we manage what we measure. But then we still must be clear regarding exactly what we intend to manage and not measure the wrong metrics or interpret them incorrectly.

A deeper layer of these problems is the debate regarding the appropriate use of different types of environmental accounting methods—attributional and consequential—over which there is still a lack of consensus (Brander et al., 2019; Ekvall, 2020; Ekvall and Weidema, 2004; Weidema et al., 2018; Yang,

[5] Another stated argument for corporate GHG reporting was that it would help prepare companies for future regulation. Yet, the GHG Protocol corporate standard did not prioritize guidance or requirements for the type of facility-level reporting necessary for such regulation.

[6] More specifically, the applied concept is a life-cycle inventory (LCI) or life-cycle inventory analysis (LCIA). Another root of these problems is viewing corporate GHG accounting as analogous to business financial accounting. Here, the use of the term "accounting" poorly serves what is better viewed as an exercise in environmental engineering estimation of physical matter and energy flows.

2019).[7] There is a lack of definitional precision for both types, but especially for attributional. Further, as I will elaborate below, and use hereafter, the term attributional is misleading and should be replaced with the term "allocational". Properly viewed, allocational (i.e., inventory) GHG accounting methods are fundamentally for the purpose of assigning responsibility for emissions to subjects. While consequential methods are for the purpose of quantifying the impact of discrete interventions. But problems and confusion are introduced in corporate GHG reporting by the application of LCA thinking that frames corporate GHG emissions inventories as accounting for all activities that a company influences or could influence. This framing conflates consequential and allocational reasoning. The practical result is the repeated attempts to introduce consequential justifications and methods into GHG Protocol corporate inventory accounting rules. Examples of this include the reoccurring desire to introduce marginal production or market-based emission factors into the GHG Protocol corporate standard. These attempts are primarily justified not through allocational reasoning (i.e., how best to assign responsibility for emissions), but through consequential, or causal, reasoning (i.e., what accounting rules will better quantify and recognize the impact of interventions and thereby incentivize mitigation actions) (Brander et al., 2018).

This "What is GHG Accounting?" series of blog installments has been interrogating the question of how to properly define and perform GHG inventory accounting. The series proposes reforms to the current corporate GHG reporting framework that address its problems and will propose a new reporting framework for companies to quantify and be recognized for the impacts of their GHG mitigation interventions.

The sections of this installment explore the conceptual problems with structuring GHG accounting as a form of LCA (see section 2). Then this installment specifically addresses how these problems are expressed within the GHG Protocol corporate standard and Scope 3 guidance (see section 3). These two sections provide framing for the rest of the "What is GHG Accounting" series.

Installment N.1 presents a typology of different types of GHG accounting with technically rigorous definitions of each type. Existing definitions for attributional environmental accounting have been problematically ambiguous. This installment fills this gap with more rigorous definitions that have substantial implications for GHG accounting standards and protocols. Installment N.2 aligns this typology and these definitions with the range of functions that stakeholders have expressed a need for corporate GHG metrics. No one form of GHG accounting can satisfy all desired functions (e.g., to exclusively allocate emissions to companies or to estimate the GHG impacts of particular interventions). Installment N.3 addresses fundamental questions regarding principles for assigning GHG emissions and setting accounting boundaries, focusing on the allocational (inventory) form of GHG accounting. Installment N.3 bis expands on the question of allocating responsibility for emissions with a philosophical exploration of the misleading influence of causal thinking.

A forthcoming installment will next apply these principles to discuss the role of market-based approaches in GHG accounting (e.g., green power purchasing claims in Scope 2, book and claim certificates for Scopes 1 or 3). Other future installments are in the pipeline that will present an alternative consequential GHG accounting framework for avoided emissions that addresses the previously explored problems and is in keeping with the elaborated definitions of proper GHG accounting.

[7] The more colloquial, and potentially superior, nomenclature is inventory and intervention accounting.

Although the analysis in this series is largely theoretical, the conclusions have practical implications for policymakers and business actors. For example, how do we reconcile the concept of corporate net zero or carbon neutral with an ambiguous or bounded assignment of responsibility? Currently, investors and other stakeholders are using corporate GHG disclosures to compare companies (Bjørn et al., 2021; Jia et al., 2022). Yet, existing protocols produce corporate reports that are, by design, not comparable. In the future, how could investors and GHG programs (e.g., Science Based Targets initiative, SBTi) use more mature forms of GHG accounting? How should companies meaningfully and practically account for their interventions that impact indirect emissions?

As a preview, a part of the solution is to reform protocols and standards on corporate GHG accounting to achieve comparable reporting between companies in the same sector, exclusively assign emissions to subjects (i.e., avoid duplicative counting of emissions), design accounting rules that establish unambiguous boundaries, and establish quantification methods that produce physically meaningful and consistent time series estimates. Such a reformed accounting framework would also address the property of additivity so that aggregate totals across companies could be meaningful at the sectoral scale.

Lastly, this series focuses on corporate GHG reporting as a policy-relevant and instructive case study to examine broader theoretical GHG accounting questions. The arguments and conclusions presented are intended to apply broadly to other forms of environmental accounting, recognizing that there are many different subjects for environmental accounting other than companies (e.g., countries, facilities, products, cities, projects, policies). GHG emissions are also a special environmental accounting topic because, unlike most other environmental burdens, GHGs are a globally well-mixed stock pollutant, which simplifies issues related to spatial and temporal disaggregation as well as pollutant fate and transport.

2 Conceptual faults in LCA

There are numerous problems with the current approach to GHG emissions and removals accounting at the level of corporations and other organizations. I argue that at the root of most of these problems is the belief that framing a corporate GHG inventory as a form of LCA will produce meaningful GHG accounting results. Although rarely made explicit, existing corporate inventory guidance and standards attempt to imitate approaches used in product LCA, but apply them to an entire corporate entity rather than a single product (i.e., good or service) (BSI, 2014; ISO, 2006; WRI/WBCSD, 2011, 2004). LCA methods were originally designed and have generally focused on assessing various kinds of environmental impacts associated with product purchasing decisions, especially those involving final consumer products. But with companies, we are not concerned only with firms that act as final consumers. Instead, we wish to address all companies regardless of where in a business value chain they operate. Corporate GHG accounting is also focused on assigning responsibility for GHG emissions to an entity, not comparing alternative consumption choices. Product level LCA, as currently practiced, has its own serious conceptual faults that have, unfortunately, been conveyed to existing corporate GHG accounting practices.

Specifically, I argue that LCA, while a useful analytical technique, should not be considered a proper method for GHG accounting. This paper expands upon the work of Brander (2016a), Brander et al. (2019), and Brander (2022) that classified various forms of GHG accounting as attributional or consequential and strived to provide a theoretical distinction between attributional and consequential GHG accounting methods. Yet, these authors' focus has been on examining and justifying the use of consequential methods. A critical research gap still exists in examining and justifying the use and limitations for attributional, or inventory, methods.[8]

The following subsections will briefly explore background on LCA, the distinctions between attributional and consequential methods, and then question the use of attributional product LCA including its problems with comparability, setting boundaries (physical and temporal), the functional unit concept, and use of environmental input/output modeling.

Brief history of LCA

The history of LCA largely begins in the late 1960s with a focus on product choices (Ekvall et al., 2005). The LCA approach aimed to assess all the various environmental impacts from processes associated with an individual product's production, use, and disposal. These assessed impacts were then to be used to compare alternative products. Interest in LCA grew in the early 1990s, as did criticism of the approach and its assumptions (Ayres, 1995; Finnveden et al., 2009). Since then, different LCA methods have been proposed and many more LCA studies of various products and other subjects have been published (Heijungs and Dekker, 2022; Yang and Campbell, 2017). Yet, despite decades of methodological development, the LCA approach has had limited use by policy makers for regulatory applications, with some concluding that product LCAs have failed to deliver "objective result[s]" (Ekvall, 2020). So, what are the problems with LCA that have limited its application?

The aLCA and cLCA distinction

A distinction that is made when considering LCA is what is generally referred to as attributional versus consequential LCA (Brander and Ascui, 2015; Curran et al., 2005; Ekvall, 2020; Finnveden et al., 2022; Guinée et al., 2018; Hellweg et al., 2023; ILCD, 2010; Pelletier and Tyedmers, 2011; Yang, 2019).[9] This distinction and terminology was more formally recognized in 2001 at a U.S. workshop on life cycle data on electricity (Ekvall and Weidema, 2004). Unfortunately, few published product LCA studies explicitly state whether they apply a consequential or attributional method (Bisinella et al., 2021).

One purpose that can be served by environmental accounting is to either exclusively allocate or non-exclusively assign responsibility for emissions to a subject, such as a product or a company (Gillenwater, 2023; Rodrigues and Domingos, 2008). In this context, attributional LCA (aLCA) has focused on the assignment of all the emissions and/or environmental impacts from the processes associated with the production, use, and disposal of a specific product.[10] The dominant use of aLCA is to compare a product's assigned emissions to the estimated value for other similar products. But, oddly, both an accepted definition and clarity on the purpose of attributional environmental accounting is still lacking in the LCA literature, which instead has had more to say on the purpose of consequential methods (Brander and Ascui, 2015; Ekvall and Weidema, 2004; Yang, 2019).[11] Early literature on the topic simply

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[8] I will also argue below that the term "attributional," which is common in literature on LCA, is itself misleading and problematic. Instead, I will introduce and use the term "allocational" to refer to inventory environmental accounting.
[9] Again, I will argue below that the term "attributional" is inappropriate and confusing and should be replaced with the term "allocational" or "inventory" when referring to this type of GHG or other environmental accounting.
[10] Although I will refer to LCA, my focus on GHG emissions would be more properly considered a focus on life cycle inventories (LCI), and that LCA would also include the assessment of the ultimate environmental impacts from GHG emissions (e.g., temperature changes or human and ecosystem damages from altered climate patterns).
[11] Historically, even the nomenclature for this form of environmental inventory accounting has lacked consensus, being referred to as "bookkeeping", "retrospective", "descriptive", "average", "non-marginal", and "traditional" accounting (Brander and Ascui, 2015; Oliver Schuller and Martin Baitz, 2020). For example, early authors using the terms retrospective and

referred to aLCA methods as a "quantitatively descriptive approach" (Curran et al., 2002). Other authors referred to aLCA as "isolating and describing the average environmental properties of a product or service life cycle" (Pelletier and Tyedmers, 2011), as a method "to quantify the total emissions from processes and material flows directly used in the life cycle of a product" (Stephen Russell, 2019), or as providing "static inventories of emissions allocated or attributed to a defined scope of responsibility" (Brander and Ascui, 2015). UNEP/SETAC defined aLCA as "a modeling approach in which inputs and outputs are attributed to the functional unit of a product system by linking and partitioning the unit processes of the system according to a normative rule" (Brander et al., 2019).[12]

In contrast, consequential LCA (cLCA) is not intended to allocate emissions but instead to quantify the "system-wide change in emissions/removals caused by a decision or intervention" (Brander, 2022; Brander and Ascui, 2015). Fundamentally, every decision to act can be viewed as an intervention, and a decision not to act then viewed as the absence of that intervention. In the context of product cLCA, an intervention is, for example, switching from the purchase and use of product A to product B.[13] Brander et al. (2019) and Ekvall and Weidema (2004) helpfully provide a theoretical distinction between attributional and consequential LCA methods, but their focus is on the role of cLCA and so do not provide a thorough theoretical definition of aLCA. They also convincingly argue that aLCA and cLCA methods should not be mixed, but each instead used for separate purposes. Combining attributional and consequential methodological elements into one time series leads to incoherent results that are a mix of physically occurring emissions and avoided emissions (Brander, 2016a; Brander and Wylie, 2011; Plevin et al., 2014; Sandén and Karlström, 2007; Stridsland et al., 2023). More broadly, there has been a long-running debate on whether aLCA or cLCA is the appropriate method for informing decision making on questions such as product or project investment choices (Brander, 2016b; Ekvall and Weidema, 2004; Nordenstam et al., 2018; Plevin et al., 2014; Soimakallio et al., 2011; Weidema et al., 2019, 2018; Zamagni et al., 2012).

Critique of aLCA comparisons

At its origins, LCA was envisioned as an analytical approach to support decision making: "The reason to perform an LCA is essentially to use it in support of a decision. A decision gives rise to a change somewhere in society compared to a scenario in which this decision was not taken. The key requirement for the LCA in any application is, therefore, that it shall reflect the environmental change caused by the decision." (Wenzel, 1998). This vision is in keeping with cLCA being the proper form of LCA. Yet, the practice of performing LCA has been dominated by aLCA studies of alternative products that are then compared for the purpose of supporting product choice decision making. The underlying assumption is that the difference between two product aLCA studies is a meaningful measure of the environmental impact caused or avoided by choosing one product versus the other. There are numerous problems with this assumption.

First, it assumes that the aLCA studies are comparable in terms of the emissions (and removals) included in the boundaries of each study. However, this assumption has not been shown to be valid (Curran et al., 2005; Ekvall, 2020; Patterson et al., 2017) in part because aLCA boundaries are subjective (i.e., arbitrary choice of where the life cycle begins and ends). Further, if aLCA results indicate that the

prospective (Ekvall et al., 2005; Tillman, 2000) were conflating the concepts of *ex post*/*ex ante* analysis with the allocational/consequential methods distinction.

[12] For discussion on the concept of functional unit see the "Unfunctional unit" section below.

[13] Consequential LCA has in the past been referred to in the literature as "change oriented", "effect-oriented", "decision based", "market-based", "marginal", and "prospective" (Brander and Ascui, 2015; Oliver Schuller and Martin Baitz, 2020).

emissions associated with the life cycle of product A are less than for product B, these results do not mean that purchasing A instead of B will result in lower emissions to the atmosphere (Plevin et al., 2010). This approach incorrectly assumes that an increase in the use of one unit of a product will result in a corresponding increase in the production of one unit of that product. In reality, there are often more complicated market-mediated effects (e.g., via price elasticities and product substitutions) that can dramatically alter one's conclusions. (Ekvall and Weidema, 2004; Plevin et al., 2014). The inadequacies of aLCA comparisons for decision making have been specifically illustrated in the context of biomass energy policy debates (Searchinger et al., 2008).

A general issue is that an intervention, such as a decision to switch products, can have effects outside of an aLCA's estimation boundary (i.e., the subject's life cycle system boundary) (Brander, 2016b; Plevin et al., 2014). If this is the case (e.g., due to non-negligible market-mediated effects), or if the boundaries of one aLCA are set more or less expansively than another, then the assumption that the boundaries are comparable is violated. Other problems that will be explored below are the assumption that estimated impacts scale linearly (i.e., the impact of purchasing 1 million units of a product is exactly 1 million times the impact of purchasing 1 unit) and that the difference in average and marginal emissions for emission sources altered by the project choices are negligible.

Although not generally presented as such, the argument implicitly being made by LCA practitioners is that one can satisfactorily approximate a product cLCA by calculating the difference between two product aLCA studies. In select cases, this approximation may be valid if all the above assumptions hold. But, even if they do hold, it is analytically more honest to disclose these simplifying assumptions and acknowledge the intention is to perform a cLCA rather than believe that aLCA is an analytically legitimate approach for quantitatively estimating the changes in environmental impacts due to product choice decisions (Brander, 2016b; Yang, 2019).[14]

Comparability

aLCA methods were developed to focus on product life cycle environmental impacts and to be as comprehensive as possible, with a focus on avoiding the shifting of impacts from one life cycle phase to another (Curran, 2014; Finnveden et al., 2009). This comprehensiveness, however, comes at the cost of comparability and aLCA studies have been found to lack comparability across products and studies of a given product (Bisinella et al., 2021). This lack of comparability, as well as high levels of uncertainty in its results, have long been a problem with aLCA methods (i.e., two aLCA studies of the same "system" typically produce significantly different results) (Ayres, 1995; Emblemsvåg and Bras, 1999; Lenzen, 2008; Moré et al., 2022; Subramanian et al., 2012). Given that the major use of aLCAs is to make product purchasing decisions by comparing aLCA results, this lack of comparability is highly problematic. Specifically, aLCA studies have been found to rely on subjective assessment boundaries (i.e., what processes to include) and co-product allocation choices (i.e., which products to allocate emissions to in co-product systems) (Patterson et al., 2017; Plevin et al., 2014; Suh et al., 2004).[15] Generally, aLCA studies also exhibit temporal (e.g., ambiguous time series interpretations because estimates are an aggregate of past, current, and future emissions, assumed product lifetimes) and

[14] These problems are amplified in cases of partial aLCAs (e.g., cradle to gate or upstream only) as they exclude some life cycle emissions (e.g., downstream) that may exhibit significant differences between products. Further, aLCA difference calculations between two products can suffer from the problems of extreme uncertainties when estimating small differences between two large numbers.

[15] Existing LCA standards and guidance do outline considerations and options for allocation in multi-function process (e.g., ILCD (2010)).

spatial (i.e., where emissions physically occur) ambiguity. The uncertainties introduced by the application of aLCA in GHG accounting are also amplified by the use of generic emissions intensity factors from LCA databases that are often based on old and non-representative studies, industry averages, and fixed commodity prices where spend-based activity data is used (Aikman et al., 2023; Matthews et al., 2008).

Why do we seek comparability in LCA and GHG accounting and what do we mean by comparability? Simply, comparability allows us to identify the similarities and differences between study subjects (Jia et al., 2022). The dominant application of aLCA, to make product choice decisions, is based on the assumption of comparability. For aLCA, comparability means that the quantified life-cycle emissions assigned to two or more subjects (e.g., products) are unbiased and therefor the difference between them provides meaningful information for decision making (e.g., selecting the product allocated less emissions is better). In contrast, cLCA methods are designed to be comparable between emission estimates for baseline and intervention scenarios. cLCA studies do not attempt to estimate all emissions occurring in both scenarios; instead, they identify the processes that change when shifting from the baseline scenario to the intervention scenario and then only estimate the change in emissions for those processes.

These problems with product aLCA are relevant for the GHG Protocol corporate standard because its accounting framework attempts to conduct a type of life cycle emissions inventory on an entire company (WRI/WBCSD, 2011, 2004). The GHG Protocol is mostly silent on the question of comparability across companies' reporting and excludes comparability as a GHG accounting principle (Gillenwater, 2022).[16][17] Yet, disconcertingly, comparability is expected, desired, and often blindly assumed to already exist by most users of corporate GHG inventory reporting.[18] This assumption by stakeholders (e.g., investors, employees, regulators) is understandable given that many of the obvious uses for publicly reported corporate GHG disclosures are to compare the environmental performance of companies (Gillenwater, 2022; Lois Guthrie, 2012).

Unfunctional units

Another problem that affects both attributional and consequential product LCAs is the concept of a functional unit. A functional unit is a quantitative unitized measure of the performance or functions that a subject (e.g., product) being studied provides (Finnveden et al., 2009). It serves as a reference unit for reporting normalized life cycle emissions intensity factors (e.g., emissions per metric tonne of rolled steel). Sometimes a functional unit can be purely based on performance, such as transportation services per passenger kilometer, which could be met by different transport modes or services.[19] In practice, a functional unit often addresses a particular product category, such as diapers (e.g., washable cloth versus disposable).

[16] There is also a rarely used international standard on LCA of entire organizations (ISO/TS 14072:2014, Requirements and guidelines for organizational life cycle assessment), which explicitly forbids comparisons between organizations (Jia et al., 2022).

[17] The designed lack of comparability in the GHG Protocol corporate standard is another reason that GHG accounting should not have been conceptualized as analogous to financial accounting, as the latter emphasizes comparability as a core principle (e.g., International Accounting Standards [IAS 1.1]) (IASB, 2017; Jia et al., 2022).

[18] In 2010, the Carbon Disclosure Project (now CDP) issued a draft framework document for the purpose of moving corporate climate disclosure reporting toward comparability but this proposal was generally opposed by stakeholders due to the reduced flexibility in setting organizational boundaries that would be necessary and the effort was abandoned by CDP (Lois Guthrie, 2012).

[19] Other functional unit examples: per square meter of usable floor area of a building for building construction, per gram of digestible protein for food production.

Results of both aLCA and cLCA studies are typically reported on a functional unit level. In aLCA studies, the total per functional unit emissions of two products are compared to make purchase decisions. Again, the implicit assumption with this approach is that this difference is a good approximation of a cLCA (i.e., the environmental impact change due to shifting from product A to product B). But, whether the per functional unit emissions are estimated based on the difference between two aLCAs or using a cLCA, they both can mislead decision making because this approach ignores intervention scale effects.

The use of functional unit emissions intensities assumes that the impact of product choice interventions scale linearly (e.g., the environmental impact of a change in purchase decisions by 100 million households can be quantified by estimating the impact of a purchase decision by one household and multiplying by 100 million) (Brander, 2016a; Ekvall and Weidema, 2004; Hauschild, 2005; Yang, 2019, 2016). The problem is that this assumption is patently erroneous. In other words, although they typically are interpreted in this manner, product aLCA results should not be interpreted to mean that increasing (decreasing) one unit of production or consumption of a product will raise (lower) emissions to the atmosphere by the per functional unit amount of emissions. Although some cLCA studies are conducted considering the specific scale of an intervention, these scale effects are often forgotten when the results are presented or used by others on a per functional unit basis. It matters whether the intervention in question relates to a consumer altering a product choice, a large company making a choice for all its customers, or a government for all its citizens. To illustrate, a small scale change in product purchases is unlikely to influence upstream raw material extraction production levels, while a large scale shift driven by a policy mandate would.

The larger the scale of the intervention (e.g., small personal decision versus national policy change) the wider the LCA boundaries will need to be to address broader market and other effects.[20] And, it is these larger, especially market-mediated effects, that a typical comparison of aLCA emission intensity factors will miss, as has been well demonstrated in the case of substituting agriculture-based biofuels for fossil fuels (Fargione et al., 2008; Searchinger et al., 2008).[21]

These market-mediated effects can be accounted for by cLCA methods, which address changes occurring on economic margins due to interventions. Yet, what production or consumption is marginal depends on the scale of the intervention. For example, we can calculate the emission intensity per functional unit of production for a factory (total emissions/total units produced). But, if we wish to understand how doubling production would impact emissions, we cannot conclude that this impact on life cycle emissions can be estimated using the existing emissions intensity value. This added production may require the construction of an entire new factory. So, even emission factors that represent marginal impacts for cLCA studies should only properly be used to estimate the impacts of interventions within a limited range of scales (e.g., small scale consumer choices or larger scale policy changes). The functional unit concept when applied to cLCA typically ignores the fact that there is not one marginal emission factor that operates at all intervention scales.

[20] For small scale interventions, cLCA is more likely to be approximated by the difference between two aLCA studies because small interventions are less likely to cause changes outside of the aLCA boundaries, assuming that both aLCA studies are comparable.

[21] For example, aLCA studies of the substitution of ethanol for petrol generally fail to account for the impacts of land use change. The added market demand and price signal for corn leads to the displacement of other agricultural activities and the expansion of agricultural land into previously uncultivated areas, resulting in a loss of biogenic carbon stocks.

The time scale of an intervention also matters. Does the intervention occur as a short-term or one time action (e.g., purchase of 100 units of a product at a single point of time) or as an extended long-term action (e.g., purchase of one product unit each month for 100 months)? Yet again, product cLCA and aLCA comparisons based on functional unit emissions intensity factors do not differentiate between short-term and long-term interventions (see Temporal confusion section below).

In sum, the concept of functional unit[22] in LCA can lead to erroneous aLCA comparisons and erroneous cLCA impact extrapolations, and therefore flawed conclusions.

Temporal confusion

The results of LCA studies have typically been presented with a large degree of temporal ambiguity (i.e., when impacts physically occur) (Beloin-Saint-Pierre et al., 2020; Bisinella et al., 2021; Finnveden et al., 2009; Levasseur et al., 2010; Lueddeckens et al., 2020; Yang and Campbell, 2017).[23] LCA studies generally do not provide a time series of emissions or impacts but instead aggregate emissions or environmental impacts over a time frame (e.g., assumed life cycle years of a product) that will include past, present, and future. This aggregation can be misleading (e.g., treats emissions estimated to have occurred years ago, as equivalent to emissions released today and to emissions expected to be released years from now) (Curran et al., 2005; Yuan et al., 2015).

Specifically, what are the temporal issues and uncertainties with LCA?

- Reported emissions are temporally aggregated, typically based on a "snapshot" at the point in time a product is produced, sold, or purchased (i.e., total estimated life cycle emissions reported as one value, which in reality occur over many years or decades).
- The lifetimes of products are assumed, and estimated emissions can be highly sensitive to this assumption (e.g., will an automobile operate for 10 or 20 years before scrappage, which would double predicted usage emissions).[24]
- Reported emissions can be a combination of historical estimates, for which data may be missing, and predicted emission estimates, the latter requiring assumptions regarding future events.
- LCA emission intensity factors taken from LCA databases can be based on outdated data and assumptions (e.g., a study of emissions from battery production processes from 20 years ago that are no longer representative of today) (Condon, 2023; De Bortoli et al., 2023).
- As discussed in the previous section, cLCA and aLCA comparison studies typically ignore the time frame over which an intervention occurs. Also, interventions can only effect future emissions, not those occurring in the past.
- LCA results can also be sensitive to the time period over which environmental impacts are quantified, which can continue past the time when an intervention ends. For example, pollutants that persist in the environment can continue to cause damage years after emissions have concluded. In the case of GHG accounting, this factor is accounted for in a comparable manner through the use of global warming potential (GWP) values (see Figure 1).

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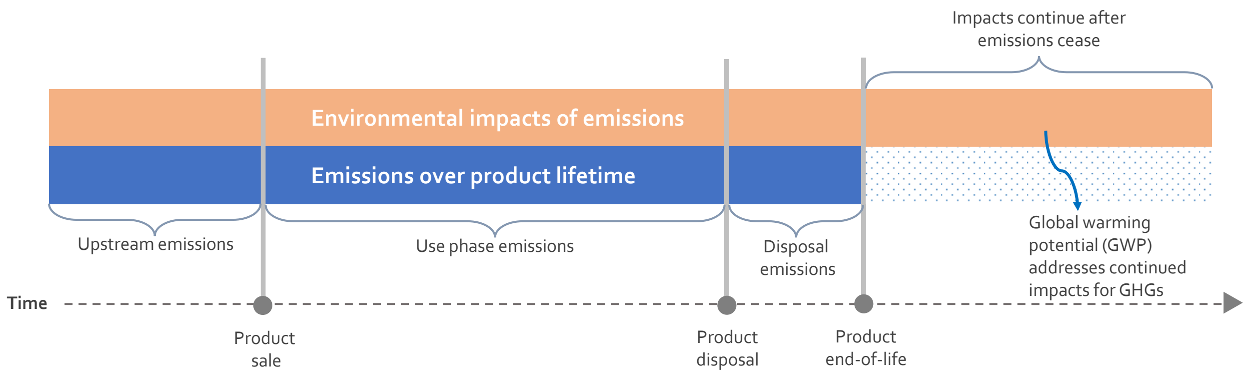
[22] In contrast to the concept of functional equivalence in project-level GHG accounting.
[23] LCA results are also typically presented with spatial ambiguity (i.e., where impacts occur), although this issue is less of a problem in the context of GHG emissions, which are global stock pollutants. In contrast, for many other pollutants impacts are greatly altered by the rate and spatial dispersion of their release.
[24] Lifetime assumptions become more complex in cases where products are recycled.

Figure 1: Temporal span of emissions and emission impacts with LCA and Scope 3



Although it is uncommon, it would be possible for both aLCA and cLCA studies to provide results in the form of a time series of emissions, in keeping with common practice with national GHG emission inventories or GHG offsetting methodologies (Brander, 2019, 2016a). Reporting impacts with temporal disaggregation have been proposed and applied in some so-called "dynamic" LCA studies (Cardellini et al., 2018; Levasseur et al., 2010).

Environmental Input-Output models

Product aLCA studies are generally conducted using either a process-based method, environmentally-extended input-output (EEIO) model, or a hybrid of the two (Huang et al., 2009b; Kennelly et al., 2019; Lenzen, 2008; Suh et al., 2004). A process-based aLCA method involves the collection of physical data (e.g., energy use, material consumption) for each process in each stage of the product's life cycle that is then used to prepare engineering estimates of emission or other environmental impacts. LCA emission intensity factor databases are often populated with data from past process-based aLCA studies, which are assumed to represent industry average values. Far-reaching process-based estimates, though, can be practically challenging to prepare for complex product life cycles (e.g., products that involve complicated supply chains).

To address these complexities, LCA EEIO models have been developed that use top-down economic statistics (in monetary units) to model transactions between defined economic sectors to which typically national emission estimates are allocated. Models can vary in their sectoral resolution, but in most cases simulate an overall economy (e.g., national, regional, or global) with broad sectors (e.g., groceries, automotive vehicles, residential buildings, freight transport) and are structured to address aggregate consumption in an economy.[25] Therefore, EEIO models sacrifice specificity (i.e., data representative of a product's specific life cycle processes) in order to apportion all final demand of an economy without double counting. The resulting sectoral EEIO emissions intensity factors used within LCA assume each of these economic sectors are homogeneous (e.g., all producers operate with identically average emissions intensity).[26]

[25] While EIO models allocate emissions to final sectoral economic demand, process-based methods can, theoretically, estimate life cycle emissions of a product at any part of the value chain (Hertwich and Wood, 2018).
[26] For some national EEIO models, foreign producers are assumed to be identical in emissions intensity to domestic producers (Lenzen, 2000). For an example of the application of an EEIO model for estimating corporate emissions see Shi et al. (2023).

For the purpose of both product LCA and corporate GHG inventories, emission intensity factors (e.g., kg CO_2-eq./dollar of spending) extracted from EEIO models have substantial limitations.[27] They provide results as the average emissions intensity of simulated product categories for each broadly defined sector, as if each sector produced one uniform commodity and all producers used identical production processes.[28] These models also generally assume proportionality between emissions and the modeled monetary flows and that prices do not vary across producers in a sector (Lenzen, 2000). In reality, the cost of products varies over time (e.g., as a function of shifting human preferences), which cannot be easily accounted for when using factors from EEIO models.

In summary, EEIO models add another layer of uncertainties on top of emissions inventory data by processing that emissions data through an economic model that itself is built upon uncertain economic statistics (e.g., national accounts) (Huang et al., 2009a; Suh et al., 2004).[29] The practical advantage of these sectoral emissions intensity factors produced by EEIO models, however, is that they can be used in combination with financial activity data (i.e., "spend data"), which offers companies the ability to produce emission estimates using their existing financial accounting data in place of collecting physical activity data from suppliers and consumers. Fundamentally, when using EEIO emission intensity factors, companies are making the questionable assumption that economic and financial data are an accurate proxy for physical emissions.[30]

What is LCA good for?

What useful information do product aLCA methods offer? They do not furnish results that are reliable for product choice decisions based on a quantified difference in emissions. This misdirected application of aLCA is premised on comparability across product aLCAs. Yet, this premise is generally invalid. And even if aLCA results for two products can be made comparable, the approach is attempting to achieve the purpose of a cLCA, which is to quantify the change in emissions from an intervention in the form of a product production or consumption decision. It is then properly viewed as a form of cLCA that involves simplifying assumptions. In the early period of LCA, Wenzel wisely argued that the only meaningful form of product LCA is cLCA because it is the only type of method appropriate for informing decision making (Wenzel, 1998). More recently, Yang (2019) correctly argued that cLCA is properly the only kind of LCA, and therefore we should eliminate both the nomenclature of attributional and consequential and refer simply to LCA, with the implicit understanding that all LCA is conducted as a consequential impact assessment of interventions using a product life cycle framing.

Like Yang (2019), I argue that aLCA is functionally useless as an environmental accounting method and should not be recognized as one. However, there is a useful role for an allocational form of environmental accounting outside the context of product LCA. Allocating, or assigning, responsibility for emissions to a subject—such as a country, company, person, or product—has essential applications, such as setting reduction targets or allocating emission budgets to subjects and tracking their progress towards meeting them (Brander, 2022, 2016b; Brander and Ascui, 2015; Marland et al., 2015). For example, the allocation of GHG emissions (and removals) to countries through national GHG inventories has been at the core of international treaty regimes, such as the Kyoto Protocol and Paris

[27] See Agye Boakye et al. (2023) for a survey of EEIO-based emission datasets.
[28] Another issue is that EIO models generally only address market goods, so any emissions associated with non-market activities that are not reflected in national economic accounts are ignored.
[29] The uncertainties in national economic accounts can vary significantly by country.
[30] If "…economic value actually provided an adequate proxy for the environmental implications of these [physical matter and energy] flows, then analyses such as LCA would be largely redundant" with financial data (Pelletier and Tyedmers, 2011).

Agreement. These applications, however, require results in the form of a consistent (i.e., statistically unbiased) time series (e.g., regularly conducted annual emissions inventory). Yet, product aLCA methods and studies generally do not produce a time series of environmental burdens, much less a consistent one (i.e., comparable over time for a given product).[31] Product aLCA studies are at best viewed as a quantitative investigation of emissions that is not appropriate for regularly tracking changes over time.

In summary, LCA techniques should be limited to two fundamental environmental analysis applications. The first is conducting quantified consequential impact assessments of interventions that have a defined scale and timeframe. And if assessment results are communicated per functional unit basis (e.g., marginal avoided emissions intensity factors), then they should indicate the range of intervention scale the factor is applicable. The second application is more suggestive than analytically determinative. LCA, including EEIO model estimates, can be used as an approach to canvass the various processes associated with a product's (or other subject's) life cycle to identify which of these processes are likely to release relatively larger fractions of emissions (i.e., a survey of emissions "hot spots"), the results of which can provide useful information to then target mitigation interventions for proper consequential accounting.

3 Is corporate GHG accounting (with Scope 3) failing?

The short answer is yes. The full answer is much lengthier to convey.

At the heart of the failure of corporate GHG accounting, as currently practiced under the GHG Protocol corporate standard (WRI/WBCSD, 2004), and associated value chain (Scope 3) guidance (WRI/WBCSD, 2011), is the belief that companies will produce a meaningful time series of emission estimates by attempting to perform a GHG-focused LCA on an entire company. This belief is erroneous because, unfortunately, the practice of corporate GHG reporting inherited the conceptual faults of LCA.

The history of the GHG Protocol is tied to the implicit goal of fostering more reporting of GHG emissions by more companies, as well as the assumption that more corporate reporting will lead to more climate action. I argue that the validity of this logic depends greatly on what is measured through this reporting and that reporting less expansively can actually lead to more action. This goal is revealed through the exceedingly expansive and flexible design of the GHG Protocol corporate standard's boundary setting rules (Green, 2010; Patchell, 2018; Walenta, 2021).[32] In other words, this design results in corporate GHG inventory reporting boundaries that are ambiguous and theoretically without limit. Another result is that inventory reports are not comparable across companies, although comparability across companies was not an explicit objective of the GHG Protocol (Gillenwater, 2022). Instead, the primary objective of the Protocol was that a single company could track its emissions over time and set targets to decrease future emissions. But, this objective requires that the estimates produced through the application of the GHG Protocol corporate standard achieve time series consistency (e.g., that the reported trend in emissions for a company over time is not just a function of shifting accounting boundaries or methodological changes). Time series consistency becomes increasingly difficult to

[31] This purpose would also require aLCA estimates to address the issue of trend uncertainty.
[32] One could easily argue that the GHG Protocol corporate standard is better classified as highly flexible guidance on GHG accounting rather than a formal "standard" (Green, 2010).

achieve as the boundaries of a corporate GHG inventory become increasingly expansive and obscure, which primarily occurs with indirect Scope 3 emissions.[33]

In the last decade increasing attention has been given to emissions occurring in corporate value chains and for companies to take greater responsibility for, report on, and mitigate these emissions (Bjørn et al., 2022, 2021; Downie and Stubbs, 2013, 2012). This attention has been justified by the argument that Scope 3 emissions comprise the vast majority of GHG emissions for most companies (Blanco et al., 2016; CDP, 2021; Downie and Stubbs, 2012; Gopalakrishnan, 2022; Hertwich and Wood, 2018; Klaaßen and Stoll, 2021; Yang and Chen, 2014). Simultaneously and paradoxically, it is increasingly recognized that comprehensively reporting Scope 3 emissions is impractical, if not impossible (Busch, 2010; Downie and Stubbs, 2013; Hansen et al., 2022; Huang et al., 2009b; Patchell, 2018). And that what is reported by companies under Scope 3 is partial (e.g., limited to tier 1 suppliers) and of poor quality (Klaaßen and Stoll, 2021; Patchell, 2018; Persefoni AI, 2022; Thorlakson et al., 2018).[34] It is not obvious or demonstrated that preparing a comprehensive Scope 3 inventory that is representative of a company's specific value chain emissions is economically or technically feasible (Patchell, 2018).

Real supply chain and consumer networks for many companies are vast and complex. For example, imagine the number of product suppliers a company like Amazon or Walmart has and then multiply that by the number of suppliers each of the corresponding manufacturers of those products have, and onwards with geometric expansion through tiered layers of suppliers and continuously shifting product catalogs. The practicality of collecting activity process data and emissions data from all these suppliers and customers, especially the farther removed they are from the reporting company (e.g., tier 2 suppliers and beyond) is obviously dubious. Such a task—expansively mapping one's value chain entities in detail, collecting specific process data from each entity, aggregating that data over a year, and repeatedly tracking operational changes in each entity over reporting years—would require a level of coordination across these networks that far exceeds existing levels of coordination and data sharing occurring through normal business transactions, which have far stronger economic incentives.[35] The task being asked of companies to report Scope 3 emissions is even beyond what sophisticated sustainable supply chain data management research studies have attempted (Patchell, 2018). It is hard to overstate the analytical ambition of the GHG Protocol Scope 3 reporting guidance.

Returning to the conceptual faults in LCA, it is primarily the attempt to include indirect Scope 3 emissions that results in corporate GHG reporting imitating an aLCA. As discussed previously, aLCA does not produce comparable results across products, much less for entire companies that produce a changing range of products. Again, I argue that aLCA should be discarded as a faulty environmental accounting methodology. Similar to aLCA, the GHG Protocol corporate guidance for value chain emissions repeatedly justifies its inventory accounting rules by stating the need for companies to account for interventions in their value chain, which is instead an argument for use of a consequential

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33 The informal terminology related to the concept of life cycle or indirect emissions can, unfortunately, be confusing and includes the terms "embodied," "consumption-based," "carbon footprint," "Scope 2 & 3," and "downstream & upstream" (Hertwich and Wood, 2018).

34 The most common categories reported under Scope 3 have been business travel and employee commuting (Blanco et al., 2016).

35 Awkwardly, the incentives for suppliers (to provide data) and companies (to collect activity data for Scope 3) are not necessarily well aligned. One of the obvious purposes of collecting supplier-specific emissions data would be to identify which suppliers have relatively higher emissions. Thus, suppliers may be providing internal process data that the requesting companies may use to justify changing to other suppliers. And therefore, many companies struggle to convince their suppliers to provide data without exerting market power (Patchell, 2018).

method. Also, like aLCA, Scope 3 suffers from time series consistency and other temporal problems that result in unreliable results (see section "Temporal confusion").

Some of these problems are acknowledged in the GHG Protocol, for example, the Scope 3 guidance states that Scope 3 estimates should not be used to compare companies (WRI/WBCSD, 2011).[36] Yet, it is an open secret that comparing companies using their corporate GHG reports prepared under the GHG Protocol is exactly what regulators, investors, and voluntary scoring and recognition initiatives are doing.

Rather than directly address the limited applications of non-comparable reports, the GHG Protocol instead focuses on another purpose for corporate GHG reporting—companies setting targets to lower emissions over time and tracking progress towards these targets with their annual emissions inventories. Yet, this purpose can only be achieved if corporate GHG inventories deliver a consistent time series, which the inclusion of Scope 3 in corporate inventories makes impractical, if not impossible.

Starting with the issue of accounting boundary setting, the following sections discuss key problems with corporate GHG reporting that attempts to apply an expansive approach to indirect emissions, as is called for by the GHG Protocol value chain (Scope 3) guidance.

Bad boundary beliefs

A core of GHG and other forms of environmental accounting is the question of boundaries. What emissions are assigned to an accounting subject, such as a company? Appropriately, this question is a focus of the GHG Protocol, which differentiates between organizational boundaries (i.e., what is deemed to be a "company") and operational boundaries (i.e., for a given company, what emissions are assigned to it for the purpose of accounting and reporting). In keeping with its roots in LCA, the GHG Protocol has established an approach to boundaries, with Scope 3, that is highly expansive. It is so expansive that few companies even attempt to report "complete" or "full" Scope 3 emissions, although they are directed to do so by the GHG Protocol (WRI/WBCSD, 2011). In response, companies are frequently criticized for not preparing and reporting complete inventories (Klaaßen and Stoll, 2021; Matthews et al., 2008). However, I argue that the problem lies more with the GHG Protocol, which does not objectively, much less practically, define completeness for a corporate GHG emissions inventory.

The GHG Protocol defines the boundaries of indirect emissions to be reported under Scope 3 by exclusion rather than inclusion—"all other indirect emissions [not included in Scopes 1 and 2] that occur in a company's value chain".[37] This explanation helps partially identify what is *not* included in Scope 3, but a better definition is needed to clarify exactly what *is* included so that it can be determined if an inventory is or is not complete. Nevertheless, the Scope 3 guidance repeatedly refers to "complete" and "full" value chain inventories, while providing no precise definition for these terms.[38] The outcome of

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[36] See page 07, section 1.5. Although little-known, an international standard for conducting an LCA on an entire company has been developed (i.e., ISO 14072), which also states that it cannot be used for comparative purposes between organizations (BSI, 2014).
[37] Page 5, section 1.3 (WRI/WBCSD, 2011). Also note that the GHG Protocol uses the term "value chain" synonymous with Scope 3 boundaries (i.e., exclusive of Scopes 1 & 2), while the common interpretation of value chain in the context of product LCA would include the all of a life cycle (i.e., inclusive of Scopes 1 & 2) (Brander and Bjørn, 2022).
[38] Table 6.1 provides generic (i.e., not associated with any specific accounting purpose or sector) and subjective criteria for the identification of relevant Scope 3 activities (WRI/WBCSD, 2011).

this ambiguity is that a company can always be criticized for not including enough in its Scope 3 inventory.

This ambiguity in the extent of Scope 3 boundaries is also one of the factors that leads corporate GHG reports to lack comparability across companies because each company engages in a bespoke selection of indirect emission sources to include in their boundaries (Patterson et al., 2017). The 2004 revised corporate standard gave each company the flexibility to selectively report only those Scope 3 emission sources it chooses based on each of their determinations of "relevance".[39] But then in 2011, GHG Protocol requirements shifted to a less flexible and more completeness-focused approach to Scope 3 with the publication of the Scope 3 guidance. "Companies shall account for all Scope 3 emissions as defined in this standard and disclose and justify any exclusions" (WRI/WBCSD, 2011).[40] To elaborate this new requirement, fifteen Scope 3 categories of upstream and downstream emissions were stipulated. In effect, Scope 3 completeness under the GHG Protocol has been defined as companies addressing all fifteen categories in their reporting (i.e., estimating emissions except where emissions are not occurring). So, do these fifteen categories answer the completeness question? Unfortunately, the answer is no.

Using categories or life cycle stages to break up value chains does not answer the question of where the boundaries of a value chain, or product life cycle, begin and end. For upstream emissions, the typical instructions from product LCA are to trace life cycles back to raw materials or the concept of a "cradle". And for downstream emissions, to trace a product to a "grave" in which products are assumed to eventually be disposed. Conceptually, this approach has some logic to it for a product LCA, given its original focus on final consumer products. But, when applied to companies, these directives do not answer the boundary completeness question, especially in the context of companies that operate far upstream of final consumer product provision.[41] For example, how should a coal mine that produces a raw material trace its value chain? Does it have no upstream Scope 3 emissions because its operations produce a raw material, and thereby is it deemed a "cradle"? Or should it account for the indirect emissions associated with the products and energy it certainly consumes to produce this raw material (e.g., excavation equipment and fuel for that equipment)? If so, then what of the company that is the immediate purchaser of this coal? Does it ignore the coal mining company's upstream emissions as a raw material producer? Similarly at the other end of an imaginary value chain is waste disposal. Does a waste disposal company, because it is deemed a "grave", have no downstream emissions even though it also consumes many products itself and produces wastes from them? Does the company sending wastes to this disposal company ignore the disposal company's downstream emissions?

Every company consumes products produced by other companies, and these connections infinitely progress and regress through suppliers and consumers, including consumers of wastes (Patterson et al., 2017). Value chain boundaries continue going on without end, eventually looping inwards on themselves. Quickly, value chain boundaries become circular. For example, in the coal mining example,

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[39] "Accounting for Scope 3 emissions need not involve a full-blown GHG life cycle analysis of all products and operations. Usually it is valuable to focus on one or two major GHG-generating activities." (WRI/WBCSD, 2004) page 29. It is not obvious how this statement is in keeping with the requirement to report "complete" scope 3 emissions.
[40] See page 60.
[41] A corporate Scope 3 inventory of indirect emissions effectively requires an organization to prepare a product LCA (i.e., cradle to gate) for all its inputs. Therefore, a corporate inventory is in some sense a hybrid of an entity-level accounting and a product LCA. In contrast, Scope 2 indirect emissions under the GHG Protocol smartly avoids ambiguity in boundary setting by delimiting itself to include only emissions occurring from the process of power generation and excludes emissions upstream and downstream of that process. Scope 2 is therefore an example of clearly delimited indirect emission allocation boundaries.

the mining company surely uses equipment made from steel, which may have been produced using coking coal from the same mine. This sort of looping is potentially ubiquitous for electricity generators, which consume products that are surely produced with electricity it previously generated. In sum, where value chains begin and end is ambiguous and subjective for any given company.

One could believe that the Scope 3 guidance provides an unintended solution to this infinite progress and regress problem through the specification of minimum boundaries for each of the fifteen Scope 3 categories.[42] Unfortunately, such a belief is mistaken. For the major upstream categories of purchased goods and services, capital goods, and fuel & energy activities (i.e., categories 1, 2, and 3) the GHG Protocol Scope 3 guidance vaguely states that each category's emissions boundaries are "all upstream," which neither addresses the completeness or infinite regress problems. Other upstream and downstream categories (i.e., 4-10, 12-14) are tied to the idea that each company should bestow to other companies downstream of it only those emissions it has reported as Scope 1 & 2 so that they may quantify their Scope 3 emissions. This results in a distortion of GHG inventory results in favor of companies whose suppliers outsource their emissions to the greatest extent (i.e., have lower Scope 1 & 2 emissions relative to Scope 3) and is another contributor to the lack of comparability of inventory reporting across companies.[43]

Establishing objective and unambiguous minimum accounting boundaries for Scope 3, while pragmatic, is at odds with the overarching justification for the expansive—and life cycle inspired—approach to indirect emissions in the GHG Protocol. A conceptual origin of the Scope 3 completeness problem is an argument repeatedly made in the GHG Protocol—that the setting of corporate GHG inventory boundaries is delimited by the potential to influence emissions from sources owned or operated by other companies, however indirectly (Brander and Wylie, 2011). For example, it is reasoned that a consumer of cement can influence emissions associated with cement production as well as further upstream limestone mining by using less cement or instead procuring from less emission intensive suppliers. This reasoning then justifies the inclusion of these upstream emission sources in a Scope 3 inventory. But, if boundary setting is justified and delimited by the potential to influence, then boundaries will have no objective limit because a company has effectively unlimited potential to influence upstream and downstream emissions through any number of decisions or actions it might take. I argue, instead, that proper allocational (inventory) GHG accounting must apply unambiguous and more narrowly delimited boundary setting rules. It is unavoidable that allocational GHG accounting (i.e., GHG inventories) will not account for every possible change in emissions that the actions of a company or other subject might influence. Further, subjectively drawing inventory accounting boundaries based on the norm of *an ability to influence* improperly relies on consequential thinking—in which boundaries for impact accounting correctly include all processes that a decision or intervention influences.

Mistaken minimalist mental model

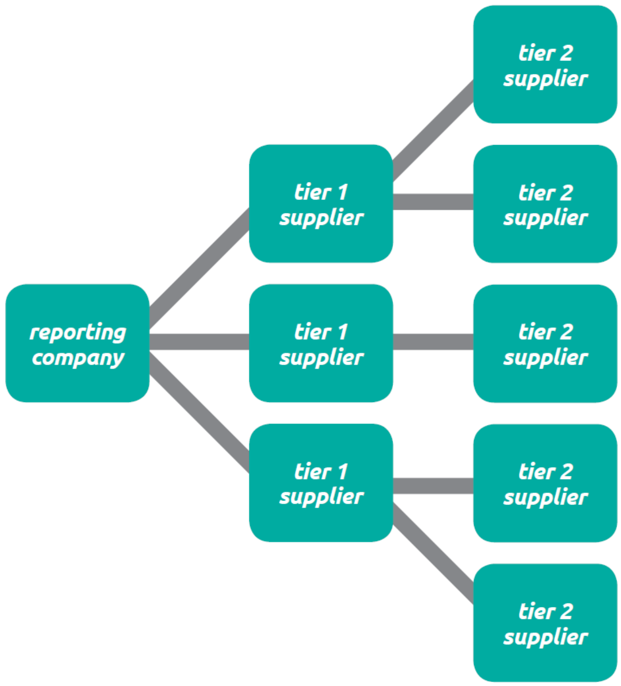
A typical multinational company can have thousands of suppliers for goods and services and thousands more customers, product servicers, and waste handlers. For such a company to collect and process emissions-related data from all of these upstream supplier and downstream consumer entities would

[42] See Table 5.4, page 32 (WRI/WBCSD, 2011).

[43] Other issues with only bestowing Scope 1 & 2 emissions downstream are that i) companies can and do use non-comparable organizational boundaries, and ii) companies face subjective decisions in how to allocate emissions to their downstream consumers or upstream waste suppliers when dealing with heterogeneous product mixes (i.e., can a company preferentially allocate all its Scope 1 & 2 emissions to one consumer or product and none to another?).

be enormously resource intensive, if not practically impossible (Robert S. Kaplan and Karthik Ramanna, 2022). Yet, explicit in the Scope 3 guidance is the expectation that companies will attempt to collect data from all these entities and all these processes. And underlying this data collection expectation is a simple mental model of supply chain tiers (see Figure 2).

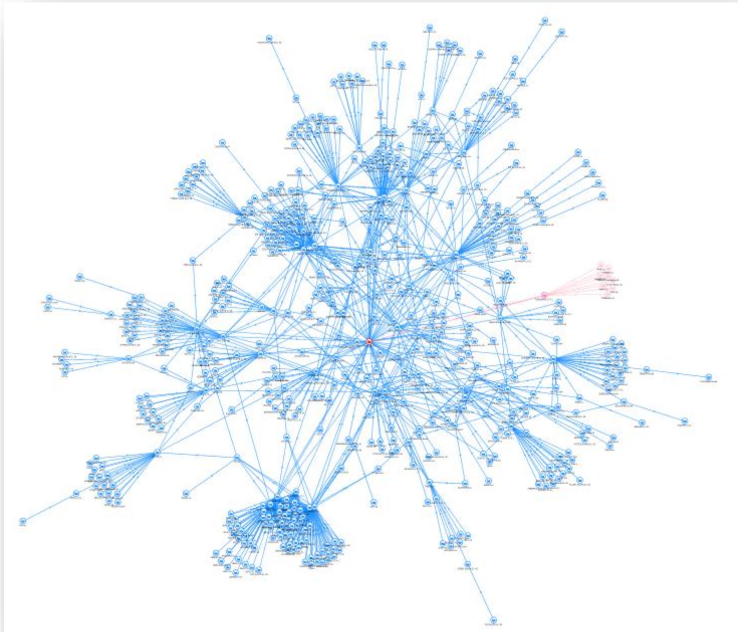
Figure 2: GHG Protocol simple supply chain tiered model[44]



This simple model assumes all companies and industries operate within a linear supply chain in which each company can systematically trace, tier by tier, their value chain until they get to a raw material producer. But, real supply chains do not fit this simple model. Modern supply chains are interconnected and better modeled as networks, including recursive loops, rather than a linear chain of relationships (O'Rourke, 2014; Patchell, 2018; Suh et al., 2004). More realistically they look like the illustration in Figure 3, with the farther reaches of such networks appearing increasingly blurry or invisible to companies (Gopalakrishnan, 2022). Most companies are unaware of who their suppliers are beyond those with whom they have direct transactions (i.e., tier 1) (Robert S. Kaplan and Karthik Ramanna, 2022). Further complicating the practical exercise of collecting emissions data from such a network is that modern supply chains are often fluid, in that they adjust based on prices and supplier availability at a higher frequency than emissions estimations, which are typically done on a cumulative annual basis.

[44] Reproduction of Figure 7.3 on page 78 of GHG Protocol Scope 3 guidance (WRI/WBCSD, 2011).

Figure 3: A more realistic representation of a single company supply chain[45]



Given Scope 3's ambiguous boundaries and flawed model of supply chains, it is currently not possible for companies to objectively determine if their Scope 3 GHG accounting is complete.[46] And therefore, it is also impossible to satisfy the requirement in the GHG Protocol that "any exclusion is disclosed and justified" because it is ambiguous what emission sources and sinks are missing.[47,48]

The Scope 3 guidance's minimum boundaries for each of the fifteen categories do not provide an objective definition of completeness, are based upon a mistaken linear concept of value chains, and neglect to address the infinite progress and regress problems. Companies instead must subjectively guess how far (and wide) upstream or downstream to go with their emissions accounting. In practice, due to the challenges in data collection from distant suppliers and future consumers, companies implicitly abdicate their boundary setting to the developers of LCA emissions intensity factors found in various LCA databases. Yet, these databases aggregate emission factors from various studies that are

[45] https://supply-chain-mapping.blogspot.com/2013/01/visualize-your-supply-chain.html?m=1

[46] Using an EEIO model to simulate a complete product life cycle, Lenzen estimated that process-based methods would need to address up to seven supply chain tiers to achieve 90% "completeness" for less energy intensive sectors. And that it would be impractical for process-based LCA methods to produce a "complete" product LCA. Instead, they found process-based LCA studies to have truncation errors on the order of 50% (Lenzen, 2000). Blanco et al. (2016) reached qualitatively similar findings of underreporting in a comparative study of actual upstream Scope 3 corporate reports against an EIO model. Huang et al. (2009a) found in an EEIO study that to achieve a high "capture rate" of emissions in a supply chain LCA often entails estimates from hundreds to thousands of suppliers, concluding that completeness has a "long tail problem."

[47] See page 60 (WRI/WBCSD, 2011).

[48] Life cycle emission factors, such as those available in LCA databases, include assumptions, often concealed, regarding the precise boundaries of what emissions are included and excluded, and therefore, are equally subject to this problem (Downie and Stubbs, 2013).

not comparable in their system boundaries.[49] In sum, the GHG Protocol Scope 3 guidance asks companies to prepare a "complete" and "full" inventory of value chain GHG emissions. However, it is ambiguous regarding what it means to do so and how one would determine if it was achieved. Research confirms the conclusion that it is probably infeasible for companies to report "complete" Scope 3 emissions as required by the GHG Protocol (Patchell, 2018).

Double duplication

In creating three reporting Scopes under the GHG Protocol corporate standard, the intention was to establish a reporting framework that addressed double counting issues, which can especially occur with the inclusion of indirect emissions in an inventory accounting framework. The stated aim of the GHG Protocol is to avoid double counting of reported emissions within a given Scope, but, by design, to allow double counting to occur between two different Scopes (i.e., the same emissions may be reported under Scope 1 by one company and under Scope 3 by another company).[50] However, this aim is obliterated with Scope 3.

First, we must clarify three types of unwanted double counting that can exist in corporate GHG reporting: 1) a unit of emissions can be reported under the same Scope by two or more companies, 2) a unit of emissions can be reported more than once under a given Scope by a single company, and 3) a unit of emissions can be reported under two different Scopes by a single company. This section focuses on the first type of double counting. However, as explained above, the looping networked structure of real supply chains means that the other two types of double counting likely occur more frequently than is recognized (e.g., when a company's suppliers are also customers for its products).

It is recognized that there is ubiquitous double counting with Scope 3, given its conceptual origins in product LCA (Gopalakrishnan, 2022; Lenzen, 2008; Lenzen et al., 2007; Marc Roston et al., 2022).[51] Like product aLCA, corporate GHG accounting for Scope 3 is structured such that the same emissions will be reported under Scope 3 by every company along a value chain.[52] So by design, Scope 3 intends every company in a value chain to effectively duplicate each other's reporting of GHG emissions. For example, a steel manufacturer reports indirect emissions from the production of coking coal in their Scope 3 report. A car manufacturer will report the same coking coal production indirect emissions in their Scope 3 report, as these emissions will be included in the LCA EF factor for the steel they use. And the company purchasing the car will report these same indirect emissions as well. The number of companies that can conduct this duplicative reporting can be vast given the problems of infinite regress and progress that result in potentially limitless boundaries of Scope 3 for a company.[53] In general, under

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[49] Little documentation is often available clearly specifying the system boundary assumptions underlying LCA database factors.

[50] "Scope 1, Scope 2, and Scope 3 are mutually exclusive for the reporting company, such that there is no double counting of emissions between the Scopes. In other words, a company's Scope 3 inventory does not include any emissions already accounted for as Scope 1 or Scope 2 by the same company." (WRI/WBCSD, 2011) page 27.

[51] Far less common, but an example of double counting between two companies within Scope 2 can occur with more than one form of energy carrier. For example, if grid-supplied electricity is used to produce chilled water and that chilled water is then sold to another company for consumption, then both companies would report the same indirect emissions as Scope 2.

[52] To be theoretically precise, the same emissions will be reported under Scope 3 by n-1 companies, where n is the number of companies along a given value chain, where one of the companies will be reporting a given unit of emissions as Scope 1. However, in practice, the Scope 3 guidance provides no objective approach to determining or limiting the value of n due to the ambiguous accounting boundaries of Scope 3.

[53] Another element of duplication under Scope 3 can occur with upstream emissions, such as from the procurement of capital goods. If a company sells, as used, a capital good after using it for half its expected lifetime, it will still have accounted for all of

the GHG Protocol Scope 3 guidance, the same unit of emissions are reported an indeterminate number of times by an indeterminate number of companies, and the theoretical sum of all corporate Scope 3 inventories would surely be many times larger than total global anthropogenic GHG emissions from all sources.

The GHG Protocol has established a distinct approach to GHG accounting, which is a mix of exclusive and non-exclusive allocation of emissions to subjects (i.e., companies). Reporting of emissions under Scope 1 and 2 is intended to be exclusive to one company (i.e., a given unit of emissions is only reported by one company under Scope 1 or 2).[54] While reporting of emissions under Scope 3 is exceedingly non-exclusive. As a result, Scope 3 reporting under the GHG Protocol is founded on the assumption that the appropriate approach to GHG reporting in some situations is exclusivity in assigning responsibility, but in other situations it is appropriate to share responsibility broadly (Weidema et al., 2018). I argue that the problem with the latter is that if many parties are assigned responsibility for something then the end result is that no one has effective responsibility. Stated crudely, when everyone is accountable for everything, then no one is really accountable.

Figure 4 illustrates different approaches to emissions allocation in a highly simplified value chain involving glass food containers. In this example, the value chain includes only four emitting processes at four companies (i.e., sand mining, glass production, glass container production, and food packaging), and the final consumers of the food products in glass containers are assumed to have no emitting processes. So, how should each of these four companies report their direct and indirect emissions? The first column in Figure 4 shows the direct (Scope 1) emissions from each company and the total emissions across all companies in this simplified value chain (i.e., 8.8 tonnes). This total is equivalent to what is physically emitted to the atmosphere (i.e., involves no double counting of emissions between companies). It also exclusively allocates emissions to each company. The second column illustrates the allocation approach of the GHG Protocol Scope 3 guidance, which includes both direct and indirect emissions and produces totals across companies that are many times the actual emissions to the atmosphere. This duplicative accounting by all companies in a value chain occurs because emissions are non-exclusively allocated to companies. Product aLCA typically avoids this double counting by exclusively allocating all emissions to a final product. But, corporate GHG accounting needs an accounting framework that can address each company along a value chain, not only the producers or consumers of final products.[55]

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the upstream emissions from the production of that capital good at the time of purchase. And the company purchasing this used capital good will then also account for the upstream emissions from the production of the capital good. What if this capital good has a 100-year lifetime and is sold to a new owner each year? Does each of these 100 owners report all of the upstream emissions? Simply apportioning emissions is impractical. When a company purchases a capital good, and therefore reports that good's upstream emissions, it may not know *a priori* how long it will use the good or if it will keep it for its full equipment lifetime or sell it used.

[54] In practice, this exclusivity may not hold true given the flexibility companies are given in defining their organizational boundaries, leading to cases in which two companies using different consolidation approaches can have overlapping Scope 1 boundaries. Although Kasperzak et al. (2023) found that an increasing majority of companies use the operational control consolidation approach.

[55] Lenzen et al. (2007) proposed an approach to exclusively allocate emissions to companies along a value chain based upon a normative rule that 50% of direct emissions are passed to the downstream companies in a value chain, which is then apportioned to those downstream companies based on their economic value add fraction of the overall value chain. Such an approach, like others that use purely financial or economic data for allocation, can problematically diverge from physical realities (e.g., can lead to odd outcomes such as the reallocation of emissions away from a company that directly emits a great deal, but adds minimal value).

Figure 4: Illustration of different value chain emissions allocation approaches, adapted from Lenzen et al. (2007)

Companies	Allocation approach: Direct emissions	Allocation approach: GHG Protocol Direct & Indirect	Allocation approach: Final Product
Sand mine	8	8.8	0
Glass	0.4	8.8	0
Glass container	0.2	8.8	0
Food	0.2	8.8	0
Final consumer	0	8.8	*8.8*
Summed emissions by allocation approach	**8.8**	**44**	**8.8**

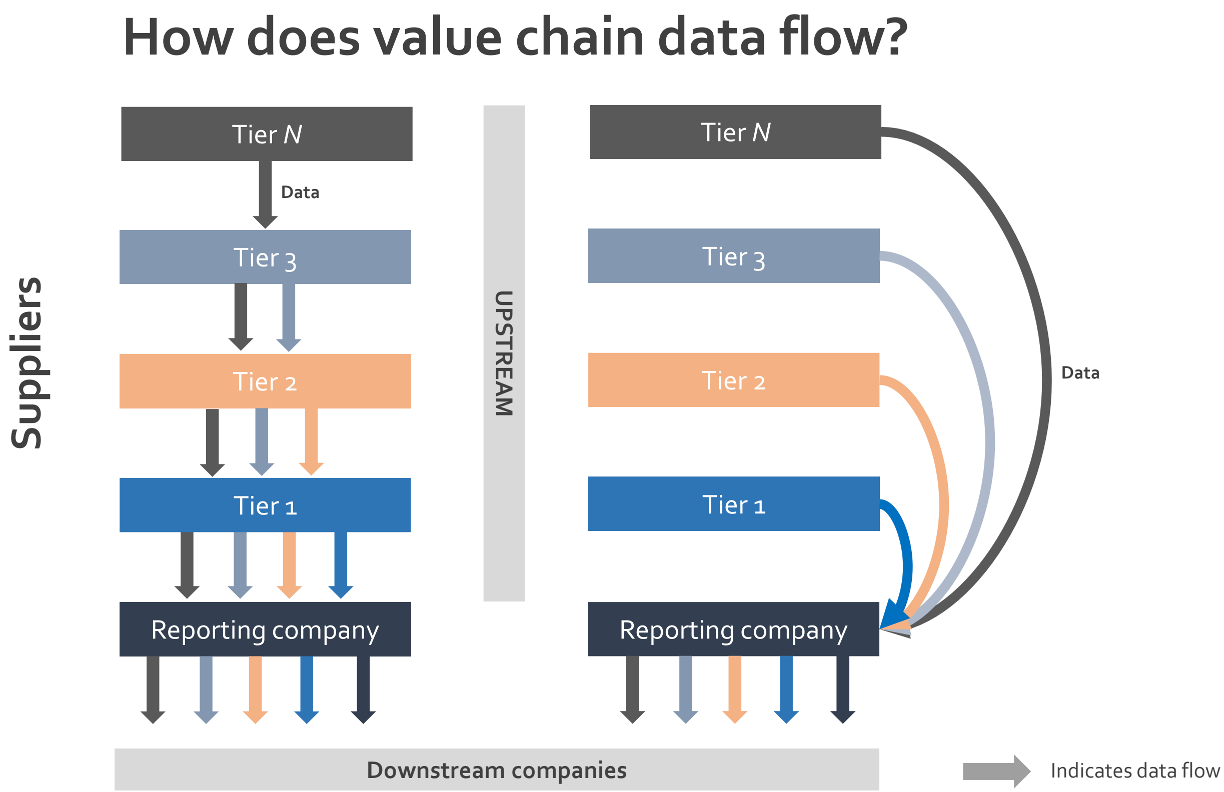
The rationale expressed by the GHG Protocol and others for this non-exclusive and duplicative approach to the reporting of indirect emissions is that multiple entities along a value chain can indirectly influence the same emissions by altering their decisions (Lenzen et al., 2007; WRI/WBCSD, 2011). Again, this rationale is related to an implicit desire to account for the impact of decisions, which is more properly addressed by a consequential, rather than allocational (inventory), method.[56] Another result of this non-exclusively shared responsibility approach to GHG accounting is that a single unit decrease in emissions to the atmosphere will be reported as a decrease under Scope 3 by every company in a value chain (i.e., many times over), which has major implications for the use of corporate GHG accounting data in voluntary or compliance schemes which give credit or recognition for reduced emissions.

Another implication of the non-exclusive assignment of Scope 3 emissions is that it introduces a practical data collection challenge. Again, crudely stated, everyone needs emissions data from everyone. Considering just the upstream portion of a value chain, the current expectation from the GHG Protocol guidance is that every reporting company will liaise with every one of its suppliers—as well as their suppliers and their suppliers, etc.—to collect emissions-related data (see Figure 5). An alternative data collection approach has been described in various forms in which accountability for emissions is allocated and passed down the value chain from company to company (Marc Roston et al., 2022; Patchell, 2018; Robert S. Kaplan and Karthik Ramanna, 2022, 2021). The problems with this alternative approach are numerous, but largely derive from its impracticality in the context of voluntary corporate reporting (i.e., where some companies choose not to participate and thereby break links in

[56] Section 8.3 of the Scope 3 guidance addressing allocation bases its instructions largely on causal or consequential arguments. It also requires additivity for emissions allocated downstream without justification, given that additivity is not required anywhere else in the Scope 3 accounting framework. (See the section in this paper on Additivity.)

the chain).[57] The commonly used alternative to both of these approaches is to instead use average GHG emission intensity factors for aggregate classes of products, often in combination with spend-based (i.e., financial) rather than physical activity data. The problem with this alternative is that it is likely to i) be unrepresentative of the conditions of a specific reporting company's actual suppliers and consumers, ii) use factors from LCA studies that are not comparable, and iii) produce results that are insensitive to changes in emissions intensity over time given that published factors are rarely updated (see next section).

Figure 5: Alternative approaches to Scope 3 supply chain emissions data collection



Lastly, it is repeatedly proclaimed that Scope 3 accounts for the majority of emissions from most companies, thereby justifying greater attention and resources being dedicated to Scope 3 emissions. The faulty logic of this claim, however, becomes clear once one realizes that the same emissions are being counted by numerous companies under Scope 3, which is not the case within Scopes 1 and 2. Scope 3 only appears as the larger portion because of its enormously duplicative counting across companies.

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[57] Specifically, the e-liabilities system proposed by Kaplan and Ramana (2022, 2021) in addition to being impractical in a voluntary participation context also suffers from a problem of emissions allocation. It requires rules for how to allocate emission liabilities to downstream consumers of each product. There will be a strong incentive to allocate e-liabilities to customers who effectively do not care (i.e., are not participating). And no product sales team will relish telling their prospective customers they must accept a load of pollution liabilities with every product they buy. Given the subjective character of LCA estimation and allocation methods, this likely lack of comparability would be enormously challenging to police for manipulation and gaming.

Scope 3 temporal tumult

Proper GHG accounting is an exercise in generating a time series of emission (and removal) estimates for the purpose of either allocating aggregate emissions over regular time periods to subjects (e.g., companies) or quantifying the emissions impact (i.e., change) from an intervention over time. Properly performed, results for both physical allocational (inventory) and consequential (intervention) GHG accounting should be presented as a time series of emissions, which is typically done at an annual frequency. With corporate GHG inventories, both Scope 1 and 2 are reported in this manner, where emissions occurring in a year are reported under that reporting year.

However, this is not the case with Scope 3. Instead, past, current, and predicted future emissions are mixed and reported together under a single reporting year without reference to which year emissions actually occur. Specifically, the GHG Protocol Scope 3 guidance instructs companies to report cumulative life cycle emissions in the reporting year that financial transactions occur rather than in the year the emissions actually physically occur.[58] Some indirect emissions occurring upstream of a company will likely have occurred in past years, while indirect emissions downstream of a company, such as through the use of its products, will occur in the future (Jia et al., 2022).[59] Therefore Scope 3 reporting of downstream indirect emissions requires predicting the future—which can obviously unfold along a range of scenarios—and then reporting these predicted emissions as if they are occurring now (i.e., in the reporting year).[60]

Further, Scope 3 also mixes annual and lifetime, or life cycle stage, cumulative emissions into one aggregate emissions total. For example, indirect emissions from employee commuting (i.e., GHG Protocol Scope 3 category 7) are reported by year in which emissions physically occur, while emissions from the use of sold products (i.e., GHG Protocol Scope 3 category 11) are reported as a cumulative total over the lifetime of the product, which can often span many years. What is the rationale for not reporting cumulative employee commuting emissions over the tenure (i.e., life cycle) of an employee with a company? Or preferably, reporting emissions occurring over a product lifetime separately for each year in which emissions physically occur (e.g., emissions from product disposal in landfills will physically occur over many years and could be reported according to the years in which emissions actually occur rather than as a cumulative number that is reported under the year that the reporting company conducted a transaction touching that product's value chain).[61] Reporting cumulative emissions over a product, capital item, or investment's lifetime under a single reporting year is another reason why Scope 3 emissions deceptively appear larger than Scope 1 or 2. And like product LCA, these

[58] For example, GHG Protocol Scope 3, category 3 addresses indirect emissions for fuels and energy "purchased and consumed" by a reporting company in the reporting year. However, purchase and consumption can happen in different years. Companies using spend data will assign these emissions to transaction year rather than consumption year.

[59] Figure 5.3 in the GHG Protocol Scope 3 guidance (WRI/WBCSD, 2011) illustrates this issue, but the guidance provides no solution to address this temporal boundary problem.

[60] For Scope 3 categories involving predicted emission estimates (e.g., sold products, investments) the GHG Protocol Scope 3 guidance (page 106) mentions that companies should update previously predicted (*ex ante*) emissions inventory estimates with *ex post* data, which in practice would require annual recalculations to all estimates for Scope 3 categories 5, 9-12, and 15.

[61] For example, the minimum boundary for GHG Protocol Scope 3 category 12 for product end of life disposal is specified as the Scope 1 & 2 emissions of the waste management companies handing product wastes. These Scope 1 & 2 emissions will be from the single applicable reporting year. Yet, most disposal emissions (e.g., landfill decay) occur over multiple years as the product decays.

cumulative emission estimates are highly sensitive to assumptions regarding future product and equipment lifetimes, which in some cases could be decades.[62]

Scope 2 reporting avoids this temporal confusion because electricity and other energy carriers (e.g., steam and chilled fluids) are roughly produced and consumed simultaneously, or if stored then only for shorter periods than an annual timeframe. And the estimation boundaries of Scope 2 intentionally include only emissions physically produced by the process generating the electricity or other energy carrier (i.e., excludes indirect emissions upstream or downstream of energy production processes).

Similar to Scope 3's indefinitely expansive operational boundaries, the rationale for this temporal boundary mixing is implicitly based on consequential (intervention) thinking, even though the purpose of corporate GHG reporting is purported to be allocational (inventorying). Specifically, reporting indirect emissions not in the year they occur, but instead as a cumulative estimate under the year a transaction occurred, is justified by the logic of influence. For example, a company's decision to produce, use, or sell a product is expected to influence emissions occurring upstream and downstream of its operations. In other words, the activities under Scope 3 inventories are being improperly regarded as interventions that have impacts rather than a subject's processes to which emissions are allocated.

Finally, what does a reported time series of emissions convey when the temporal boundaries of each corporate emissions total is a confusing mix of aggregate annual and cumulative lifetime emissions, as well as past, current, and future emissions? I would argue that as currently structured, the GHG Protocol Scope 3 guidance fails to produce results that can be interpreted as a meaningful emissions time series for tracking performance (Beloin-Saint-Pierre et al., 2020).

Meaningless metric

A fundamental argument made for Scope 3 reporting is that companies can compel their suppliers and consumers to provide emissions information and then influence these suppliers and customers to implement emission reduction actions (Patchell, 2018). Engaging with suppliers and consumers for the purpose of promoting GHG mitigation is a laudable goal. It can be informative for a company to examine its value chain to identify which of its suppliers' and customers' processes lead to relatively greater emissions. And then use this information to target subsequent work to identify mitigation options for analysis and implementation. But, these are arguments for conducting an investigation, not arguments for regularly producing estimates that can be used as a consistent time series showing meaningful changes and trends over time as a reliable measure of performance.

Scope 3 reporting under the GHG Protocol entails ambiguous and overly expansive accounting boundaries, highly duplicative reporting that inflates the importance of Scope 3 (relative to Scopes 1 and 2) and dilutes the allocation of responsibility for emissions, and awkwardly mixes different time frames and temporal aggregations of emissions. As a result, Scope 3 reporting is not capable of or useful for setting emission reduction targets and tracking progress towards those targets over time. Further, corporate GHG inventories, as currently prepared under the GHG Protocol, cannot be used to

[62] The GHG Protocol guidance describes the exercise of estimating Scope 3 emissions for category 15 (investments) as a snapshot of emissions reflecting the product and supplier mix for an investment portfolio composition at one moment in time (e.g., on 31 December each year). Such an exercise is not really an accounting of aggregate emissions allocated to a company or its investments over a year. A company wishing to game these rules could simply choose to sell off its high emitting investment on the day the snapshot is taken and then repurchase the next day.

compare companies in any given year, much less compare their performance over time. Previous studies have concluded that corporate Scope 3 reporting does not produce comparable emission estimates across companies and that "improvements" to guidance have not appeared to resolve this problem (Busch et al., 2022; Downie and Stubbs, 2012; Klaaßen and Stoll, 2021).

The annual estimates that are produced using the Scope 3 guidance are also generally not representative of the specific company reporting them. The GHG Protocol encourages companies to use supplier- and consumer-specific process emissions data. However, given the data collection challenges with Scope 3, most companies use industry average emission intensity factors from LCA databases. Because these are fixed industry averages that are rarely updated and typically outdated, the resulting emissions estimates are insensitive to changes in suppliers or to changes that the suppliers make in their processes. Only major structural changes that a company makes in its supply chain or product offerings that entail using an average emission intensity factor for a different input product (e.g., changing to a completely different input material for production, such as from steel to plastic) will be reflected as a change in estimated Scope 3 emissions. Scope 3 reporting generally fails to account for the very impacts resulting from the influence that Scope 3 reporting is supposed to be encouraging reporting companies to exert.

Collecting the enormous amount of data and preparing emission estimates in keeping with the GHG Protocol Scope 3 guidance *every year* also entails significant costs for a company. Therefore, the value of the resulting estimates should have at least a similar value in terms of their usefulness. Again, I argue that it can be useful for a company to broadly examine its value chain so as to roughly identify major emission sources within suppliers' and consumers' operations. But this task should be less expansive and frequent than the current approach to Scope 3 reporting. Instead, companies can obtain more valuable information by redirecting their resources addressing distant indirect emissions to the application of consequential GHG accounting methods for preparing *ex ante* estimates of the impacts of mitigation options and then *ex post* estimates of the impacts of implemented interventions. In other words, GHG accounting that addresses a company's value chain is more legitimately performed by quantifying the avoided emissions from GHG mitigation interventions a company makes in its value chain.

Again, a root of the problems with Scope 3 reporting is that it is presented as an allocational (inventory) form of GHG accounting, but the justifications for why companies should do it are derived from consequential thinking.[63] The GHG Protocol Scope 3 standard states its function as to "help companies understand their full value chain emissions impact…to focus company efforts on the greatest GHG reduction opportunities." (WRI/WBCSD, 2011)[64] This statement is appropriate if we interpret "understand" not to mean reliably quantify over time, but instead simply to investigate in a quantitative manner. As explained above, the term "full" is inappropriate, as it is ambiguous as to what a full or complete understanding would entail. And there is little with regard to Scope 3 accounting that meaningfully focuses on GHG mitigation opportunities beyond identifying major sources of emissions and removals. We must accept the fact that GHG inventories cannot account for the impact of most interventions because proper emission inventories have limited accounting boundaries—interventions will often have effects outside of those boundaries—and the impact of interventions is not isolated in emissions inventories and so can be masked by other factors such as weather (e.g., increased heating

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[63] For example, the GHG Protocol Scope 3 guidance for category 15 (investments) refers to estimating emissions of a "project", which refers to a consequential form of GHG accounting.
[64] See page 04, section 1.2

demand) and production output (e.g., a temporary shutdown for maintenance in a production line). The World Resources Institute has itself recognized that consequential, not allocational (inventory) methods, should be used to inform decision making (Stephen Russell, 2019).

In sum, attempting to perform what is effectively an LCA on an entire company does not deliver a meaningful time series metric upon which corporate environmental performance can be physically measured. It does not usefully assign responsibility for emissions. And in the case of Scope 3, reported emissions appear deceptively large relative to other Scopes because of duplicative reporting across companies and the reporting of cumulative multi-year lifecycle emissions under single reporting years. It is not actually obvious what data on Scope 3, even if done "fully," would be useful for. Given its uncertainties, reported Scope 3 emissions would seem to be useless for policy making and regulatory applications (Geoffrey Heal, 2022).[65]

Ultimately, the objective of corporate GHG reporting should be to provide quantitative results that reflect physical emissions to the atmosphere, or changes in those emissions, over time. The objective is not to attempt to produce GHG emission inventories that include as many indirect emission sources as we can model. Expansive life cycle thinking does not lead to workable GHG accounting methods that produce comparable or consistent time series results. Using life cycle thinking can be useful for conducting a systems analysis that identifies major emitting processes along a value chain (i.e., hot spots), but it is inappropriate for GHG accounting.

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https://ghginstitute.org/2023/12/19/what-is-greenhouse-gas-accounting-turning-away-from-lca/

[65] A policy application of LCA-inspired GHG metrics is the case of low carbon fuel standards (LCFS), such as in the states of California and Washington (USA). Although LCFS policies do not attempt to generate time series estimates using LCA methods, but instead apply a default quantification of partial life cycle GHG emissions to a narrow range of categories (i.e., fuels or other energy carriers) for a crediting program (Mandegari et al., 2023).

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