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Transposing lessons between different forms of consequential greenhouse gas accounting: lessons for consequential life cycle assessment, project-level accounting, and policy-level accounting

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ABSTRACT

Greenhouse gas accounting has developed in a number of semi-isolated fields of practice and there appears to be considerable opportunity for transposing methodological innovations and lessons between these different fields. This research paper identifies three consequential forms of greenhouse gas accounting: consequential life cycle assessment; project-level accounting; and policy-level accounting. These methods are described in detail and then compared in order to identify the key methodological differences and the potential lessons that can be transposed between them. Analysis of the substantive methodological differences suggests that consequential life cycle assessment could be enhanced by adopting the same structure used in project and policy-level accounting, which provides a time-series of impacts, aggregate level analysis, and a transparent specification of the baseline and decision scenarios. There is a case for conceptualising a unified form of consequential time-series assessment, of which project, policy and product assessments would be sub-types.

1. Introduction

Greenhouse gas accounting has developed in a number of distinct fields of practice (Ascui and Lovell, 2011; Marland et al., 2013), and as a result there appears to be considerable potential for transposing conceptual or methodological innovations from one field of practice to others. Greenhouse gas accounting methods have developed at the national level (Penman et al., 2006), the organisational level (WBCSD/WRI, 2004), the product level (British Standards Institute, 2011; WBCSD/WRI, 2011b), the project level (ISO, 2006d; WBCSD/WRI, 2005), in addition to others. It may be assumed that when such methods have similar purposes but employ different methodological approaches, there is an opportunity for comparing those approaches and generating lessons for potential methodological development.

One grouping of methods, which forms the focus of this paper, is the set of greenhouse gas accounting methods that can be described as 'consequential' in nature. The term 'consequential' originates within the field of life cycle assessment (LCA) (Curran et al., 2005; Russell et al., 2005), but the concept can be used more broadly to denote any form of assessment which aims to quantify the total *change* in impacts that results from a given decision or intervention (Brander and Wylie, 2011). Consequential methods are often contrasted with 'attributional' methods (Reinhard and Zah, 2009; Tufvesson et al., 2013; Finnveden et al., 2009), which can be defined in a broad sense to denote any inventory of *absolute impacts* attributed to a given entity, such as a country, organisation, or product (Brander and Wylie, 2011; CDP, 2013), with attribution normally based on some form of physical connectedness. The focus of this paper is on the lessons that can be shared between different *consequential* methods, though some discussion of attributional methods will also be provided where this helps to explain certain features of the consequential approaches in question.

The novel contribution of this paper is the identification of *methodological* lessons that can be shared across different fields of greenhouse gas accounting practice. The academic literature on greenhouse gas accounting *methods* tends to exist within narrow communities of practice, such as the life cycle assessment community or the project accounting community, and there appears to be a significant lack of *methodological* dialogue between such fields. For example, the recent development of dynamic life cycle assessment (Beloin-Saint-Pierre et al., 2014; Collet et al., 2013) can

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be viewed as a reinvention of time-series assessment but without reference to, and some years after, project-level accounting. Greater awareness of the methodological innovations within other areas of practice may be fruitful in guiding and facilitating similar methodological developments. The existing literature that does take a more holistic view across different fields of greenhouse gas accounting practice has tended to take a social theory perspective, and considers issues such as the distinct social purposes of greenhouse gas accounting (Ascui and Lovell, 2011; Schaltegger and Csutora, 2012), or how accounting practices and competence are socially constructed (MacKenzie, 2009; Ascui and Lovell, 2012; Burritt and Tingey-Holyoak, 2012). However, as yet there is very little research on transposing methodological lessons, notwithstanding the *prima facie* likelihood that there is much to be learnt.

The primary contribution of this paper is the identification of methodological lessons that can be transposed between different forms of consequential greenhouse gas accounting, however, in pursuing this end the paper also provides some supplementary outputs: a classification of current greenhouse gas accounting methods according to whether they are consequential or attributional in nature; and a detailed discussion on the core and superficial methodological characteristics of the identified consequential methods. Although this paper is primarily focused on greenhouse gas accounting, the findings are relevant to consequential methods that consider other impact categories as well.

2. Methodology

This paper proceeds by identifying the existing forms of greenhouse gas accounting through a review of the current accounting standards and guidance, and classifies these methods as being either consequential or attributional in nature.

A list of published standards and guidance for physical greenhouse gas accounting was compiled based on existing knowledge of the main organisations publishing such guidance, such as the International Organization for Standardization, the Greenhouse Gas Protocol, and the Intergovernmental Panel on Climate Change, and also an internet search for ‘greenhouse gas guidance’, ‘carbon guidance’, ‘GHG guidance’ and ‘LCA guidance’. An initial list of standards was compiled in early 2014, and was updated in early 2015 to achieve a more complete list at the time of publication. The list of standards collected is not intended to be exhaustive, and given the proliferation of standards and sector-specific guidance any list would become incomplete rapidly. However, the list of collected documents is sufficient for the present purpose of identifying the main consequential forms of greenhouse gas accounting and their methodological features.

Only standards and guidance for physical greenhouse gas accounting, as distinct from financial greenhouse gas accounting, were included as the purpose of financial accounting was considered sufficiently different that the transposition of methodological lessons would be unlikely. Physical greenhouse gas accounting is concerned with flows or changes in greenhouse gases in mass units, such as tonnes of CO_2e, while in contrast financial greenhouse gas accounting is concerned with the financial value of carbon-based assets and liabilities, such as tradable emission permits or reduction credits, measured in monetary units.

The collected standards were then classified as being either consequential or attributional in nature. The defining characteristics of consequential greenhouse gas accounting methods are taken to be: 1. the method aims to quantify *change* in emissions/removals, resulting from a decision or action; 2. the method aims to quantify *system-wide* change (i.e. not only change within a limited boundary). The criterion used to identify attributional methods is: the method aims to quantify and allocate absolute emissions/removals to a given entity or item. These defining characteristics are those identified in Brander and Ascui (2015), which collates a number of definitions for the 'consequential' and 'attributional' approaches in the LCA literature, and provides an analysis of the essential and supplementary features of the two types of approach.

As with many conceptual distinctions, there is ongoing debate as to its precise nature and implications (Suh and Yang, 2014; R. J. Plevin et al., 2014a; Brander and Ascui, 2015). Nevertheless, the nuances of that debate are sufficiently fine-grained that any alternative interpretations are highly unlikely to yield alternative classifications of the published greenhouse gas accounting standards. In the instances where classification did prove difficult, this tended to arise because the standard in question mixes both consequential and attributional elements, rather than because the classification criteria are unclear. It is worth noting that this situation can be distinguished from cases where the standard in question clearly intends to address both methods separately, within a single document (e.g. the ILCD handbook (European Commission et al., 2010)). The instances where classification was uncertain are discussed further in Section 3.1.

Some of the standards and guidance documents identified cover a wider range of impact categories than just greenhouse gas emissions, but were nevertheless included in the analysis if they covered greenhouse gas emissions as an impact category. The standards and guidance documents were then grouped by the type of entity or action they primarily relate to, e.g. national level, community level, product level etc. Table 1 in Section 3.1 presents the guidance and standards reviewed, and their categorisation by type.

The identified consequential methods are then described in detail, setting out the key steps and structure of each method. This information is then used to analyse any substantive differences between the methods and to identify the potential lessons for methodological development.

3. Results and discussion

This section presents the findings from the review and classification of existing greenhouse gas accounting methods, a detailed description of each of the consequential methods identified, and an analysis of the main methodological differences and potential lessons for the development of the methods.

3.1. Review and classification of existing greenhouse gas accounting methods

As noted above, there were a number of instances where it was more difficult to categorise a standard/guidance document as being either consequential or attributional, largely because the standard/guidance in question is ambiguous or mixes elements of both approaches in a single methodology. This is the case with the Greenhouse Gas Protocol's Product Life Cycle Accounting and Reporting Standard (WBCSD/WRI, 2011b), which explicitly states that it is intended as an attributional method but allows the use of substitution when dealing with multi-functionality, though substitution is generally regarded as a consequential modelling technique (Brander and Wylie, 2011). A similar issue arises with ISO 14040:2006 (ISO, 2006a) and ISO 14044:2006 (ISO, 2006b), though in these cases neither standard states whether it is intended to represent a consequential or attributional method, or both simultaneously. ISO 14040 uses the term “allocation procedures” which suggests an attributional method, though ISO 14044 allows both substitution and allocation. The failure of these standards to actually standardise practice is well noted by Weidema (Weidema, 2014), however, for the purposes of the current analysis these ISO standards have been classified as attributional as they contain no

Table 1
Categorisation of greenhouse gas accounting methods.

Consequential methods		Attributional methods	
Entity/Action	Guidance/Standard	Entity/Action	Guidance/Standard
Product (consequential LCA)	1. International Reference Life Cycle Data System Handbook (European Commission et al., 2010) 2. Market information in life cycle assessment (Weidema, 2003) 3. Guidelines for application of deepened and broadened LCA (Weidema et al., 2009)	Product (attributional LCA)	1. International Reference Life Cycle Data System Handbook (European Commission et al., 2010) 2. PAS 2050:2011 Specification for the assessment of the life cycle greenhouse gas emissions of goods and services (British Standards Institute, 2011) 3. Greenhouse Gas Protocol: Product Life Cycle Accounting and Reporting Standard (WBCSD/WRI, 2011b) 4. ISO 14040:2006 (ISO, 2006a) 5. ISO 14044:2006 (ISO, 2006b) 6. ISO/TS 14067:2013 (ISO, 2013b) 7. Product Environmental Footprint (European Commission, 2013)
Project	1. GHG Protocol for Project Accounting (WBCSD/WRI, 2005) 2. ISO 14064-2:2006 (ISO, 2006d) 3. Clean Development Mechanism methodologies (UNFCCC, 2014) 4. Verified Carbon Standard methodologies (Verified Carbon Standard, 2014)	Organisational	1. Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard (WBCSD/WRI, 2004) 2. Greenhouse Gas Protocol: Corporate Value Chain (Scope 3) Accounting and Reporting Standard (WBCSD/WRI, 2011a) 3. ISO14064-1:2006 (ISO, 2006c) 4. ISO 14069:2013 (ISO, 2013a) 5. Organisation Environmental Footprint (European Commission, 2013)
Policy	1. Greenhouse Gas Protocol: Policy and Action Standard – Final Draft (WBCSD/WRI, 2014)	Community	1. Global Protocol for Community-Scale Greenhouse Gas Emissions (GPC) (Schultz et al., 2014) 2. PAS 2070: 2013 Specification for the assessment of greenhouse gas emissions of a city (British Standards Institute, 2013) 3. U.S. Community Protocol for Accounting and Reporting of Greenhouse Gas Emissions – version 1.1 (ICLEI, 2013)
		National	1. IPCC Guidelines for National Greenhouse Gas Inventories 2006 (Penman et al., 2006)

specifically consequential modelling requirements, other than the inclusion of substitution in ISO 14044, which appears to be an aberration similar to that in the GHG Protocol standard.

The same aberration is present, but seemingly deliberately so, in both the Organisation Environmental Footprint and the Product Environmental Footprint methods (European Commission, 2013). As a general principle, attributional methods should only include values for absolute emissions and absolute removals, and should not include values for avoided emissions, which is the implication of using substitution (Brander and Wylie, 2011). Combining both attributional and consequential elements in a single analysis means that the results are neither an inventory of absolute emissions/removals, nor a complete assessment of change, and are effectively incoherent (R. Plevin et al., 2014; Brander and Wylie, 2011).

The review and classification exercise identified three main forms of consequential assessment: consequential life cycle assessment; project greenhouse gas accounting; and policy greenhouse gas accounting. These methods share the general 'consequential' characteristics of aiming to quantify change in emissions/removals resulting from a decision or intervention, and quantifying that change wherever it occurs (i.e. not only within a limited boundary). In the case of consequential life cycle assessment (consequential LCA) the intervention in question relates to the production or consumption of a product, or changes in the configuration of the life cycle of a product (Weidema, 2003). For project accounting the intervention is the implementation of a project, which can be defined as a set of activities intended to cause a change in greenhouse gas emissions (ISO, 2006d; WBCSD/WRI, 2005). Lastly, in the case of policy accounting the intervention is any policy, such as a tax, payment incentive, market mechanism etc. (WBCSD/WRI, 2013). Although policies are normally implemented by governments or public agencies, the method can equally be applied to policies implemented by corporations.

The grouping of the identified consequential standards as being 'product', 'project' or 'policy' methods is based on the stated level of action each standard aims to address, e.g. ISO 14064-2 (ISO, 2006d) states that it is for the quantification of emissions and removals at the *project* level, and has therefore been grouped with other project level methodologies. However, it is important to note that the groupings chosen do not entail mutual exclusivity, e.g. consequential LCA is described as a *product* level method although it can be, and often is, used for policy analysis (R. J. Plevin et al., 2014b; Searchinger et al., 2008), albeit only where the policy relates to changes in the supply or configuration of products.

The following three sections provide detailed outlines of each of these methods in order to facilitate the subsequent analysis of their key differences and similarities, and the opportunities for sharing lessons between them.

3.2. Consequential life cycle assessment

Consequential LCA aims to quantify the changes in impacts that result from a change in the level of production of a product, or changes in the configuration of the life cycle of a product (Weidema, 2003). It is worth noting that this method developed out of conventional attributional LCA in the 1990s (Weidema, 1993; Zamagni et al., 2012), and as a result consequential LCA still contains much of the methodological structure and conceptual apparatus of its attributional forebear, which is of relevance to the later discussion in Section 3.5. The 'life cycle' of a product can be defined as "the consecutive and interlinked stages of a product system, from raw material acquisition or generation from natural resources to final disposal" (ISO, 2006b, p.2). Table 2 provides a summary of the generic steps used in implementing an LCA (largely adapted from the *International Reference Life Cycle Data System Handbook* [European Commission et al., 2010])

Table 2
Key steps in product LCA.

Step 1 – goal definition	Define the intended application of the study (e.g. to inform decision-making, make marketing claims etc), and the intended audience for the results.
Step 2 – scope definition	Define a number of features of the study, including the product that is studied, and the 'functional unit'. The 'functional unit' is the "quantified performance of a product system for use as a reference unit" (ISO, 2006b, p.4), and is used to ensure that products are compared on a like-for-like basis (Weidema, 2003).
Step 3 – inventory analysis	Identify the processes to include within the assessment, and collect data on the material and energy flows associated with those processes. For a consequential LCA the processes that are inventoried are the 'marginal' processes, i.e. the processes that change as a result of the decision in question (Schmidt and Weidema, 2008). These processes are often, but not always, different to those used directly in the life cycle of the product physically produced/consumed (i.e. those that would be included in the inventory for an attributional assessment).
Step 4 – impact assessment	Convert the information on material and energy flows into impacts. In the case of greenhouse gas emissions this generally involves the use of emission factors and the conversion of non-CO_2 greenhouse gases into CO_2e by the use of global warming potentials.
Step 5 – interpretation	Identify the significant findings of the assessment and relate these to the goal of the study. This is often considered an iterative or concurrent process that feeds back into the other stages of the method as the assessment progresses (European Commission et al., 2010).

The main difference between attributional and consequential LCA relates to the processes that are included in the inventory stage (step 3) of the assessment (Zamagni et al., 2012). Consequential life cycle inventory includes all and only the processes that *change*, wherever they occur in the system, while in contrast an attributional life cycle inventory includes the processes used directly in the life cycle stages of the product physically produced/consumed. This difference is illustrated by the use of the technique of substitution in consequential LCA, which is used to deal with co-products, or other forms of multi-functionality. Substitution involves identifying the product systems that are displaced (i.e. *changed*) by the production of co-products, and crediting the displacement of those product systems to the decision studied, as the avoidance of those systems and their associated impacts are a consequence of the decision (Ekvall and Weidema, 2004; Brander and Wylie, 2011).

An early formulation of a general procedure for identifying the processes that change, i.e. the 'marginal' processes, is provided by Weidema et al. (1999), in which considerations such as the time horizon of the study are taken into account:

> One should distinguish between short-term, when studying changes which take place with the existing production capacity and which are not expected to affect capital investment (installation of new machinery or phasing out of old machinery), and long-term, when studying changes that are expected to affect capital equipment.
>
> Weidema et al., 1999, p.49.

From such initially straightforward procedures there has been a continual development of methods for identifying the processes that change, such as the inclusion of positive feed-back loops through economies of scale and learning (Sandén and Karlström, 2007); procedures for determining the proportion of increased agricultural output from yield increases, land use change, or reduced consumption elsewhere (Schmidt, 2008); and the use of general equilibrium modelling to predict the world regions that will respond to changes in commodity prices (Searchinger et al., 2008; Hertel et al., 2010).

A further important feature of both consequential and attributional LCA is the use of *amortisation*, which is required when there are large non-linear emission events over time, such as land-use change or the production of capital equipment (Sjödin and Grönkvist, 2004; Hsu et al., 2010; Searchinger et al., 2008; Hertel et al., 2010). The need for amortisation is ultimately driven by the fact that LCA calculates impacts on a normalised per product (or per functional unit) basis, for example, Searchinger et al. (2008) present their findings in gCO_2e/MJ of fuel. Amortisation allows temporally distributed non-linear impacts, such as land use change, to be averaged by the amount of production during a specified period of time. This feature of consequential LCA will be contrasted with the approach taken by the other consequential methods in Section 3.5.

3.3. *Project accounting*

Project accounting aims to quantify the changes in emissions or removals that occur as a result of a project (WBCSD/WRI, 2005), with 'project' broadly understood as a "planned set of activities within a specific geographical location" (Watson et al., 2000, sec.5.1.2).[1] In general, the background context for the development of project accounting is markedly different from consequential LCA, as its focus has been primarily on crediting greenhouse gas emission offsets (Gustavsson et al., 2000), rather than informing decision-making with respect to a range of possible options. One exception to this is ISO 14064-2, which was intended to also accommodate the quantification of internal abatement actions and technology choices.

As shown in Table 1, project accounting has been formalised in a number of standards and guidance documents, including the *GHG Protocol for Project Accounting* (WBCSD/WRI, 2005), and *ISO 14064-2 Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emission reductions or removal enhancements* (ISO, 2006d). There are also numerous methodologies for specific project-types, such as those under the Clean Development Mechanism (UNFCCC, 2014), or the Verified Carbon Standard (Verified Carbon Standard, 2014). Table 3 presents the key steps in project accounting, based on *ISO 14064-2*, with some details also taken from the *GHG Protocol for Project Accounting*.

The schematic diagram in Fig. 1 below provides a graphical illustration of the main components and overall structure of the project accounting method.

There are a number of key features illustrated by Fig. 1 that are worth highlighting as they are particularly relevant to categorising the main differences between the various consequential methods in Section 3.5. Firstly, Fig. 1 illustrates the way the change caused by a project is calculated as the difference between the baseline and project scenario, with the scenario in which the project is absent (the baseline) being transparently and explicitly modelled. This basic structure to the method can expressed as follows in Equation (1).

[1] A more precise name for the practices commonly denoted by the label 'project accounting' would be 'consequential project accounting' as in theory attributional accounting could also be applied at a project level. However, 'project accounting' is used in this paper as it is the label commonly used to denote consequential project accounting, and to-date the need to distinguish between consequential and attributional methods at the project level has not arisen.

Table 3
Key steps in project accounting.

Step 1 – describe the project	Describe the physical location of the project and the activities that will be undertaken to reduce greenhouse gas emissions (ISO, 2006d, sec.5.2).
Step 2 - identify the greenhouse gas sources and sinks relevant to the project	All sources and sinks that are controlled by, related to, or affected by the project should be included in the assessment (ISO, 2006d, sec.5.3). This step appears to parallel the life cycle inventory stage for consequential LCA (step 3), i.e. identifying all emission sources that change as a result of the intervention in question.
Step 3 - determine the baseline scenario	The baseline scenario can be defined as a "hypothetical reference case that best represents the conditions most likely to occur in the absence of a proposed greenhouse gas project" (ISO, 2006d, p.3). ISO 14064-2 requires that the baseline scenario be equivalent to the 'with project' scenario in terms of the supply of products and services (ISO, 2006d, sec.5.4), which parallels the requirement for equivalent 'functional units' when comparing product systems in consequential LCA.
Step 4 - identify greenhouse gas sources and sinks for the baseline scenario	This is a parallel process to Step 2, but for the baseline rather than project scenario (ISO, 2006d, sec.5.5)
Step 5 - quantify greenhouse gas emissions or removals	For each source or sink identified in the 'with project' and 'baseline' scenario, the level of emissions/removals should be calculated, e.g. by applying emission factors to activity data for each source and sink (ISO, 2006d, sec.5.7). This is similar to the 'life cycle impact assessment' stage in consequential LCA (step 4).
Step 6 - quantify emission reductions and/or removal enhancements	This is done by subtracting the 'with project' emissions/removals from the 'baseline' emissions/removals, for each year that the project is in operation (ISO, 2006d, sec.5.8; WBCSD/WRI, 2005, p.77)

$$\textit{Change in emissions} = \textit{Net baseline emissions} - \textit{Net project scenario emissions} \quad (1)$$

A second key feature of the method is that emissions are presented as a time series. This means that the method can capture the 'shape' of the change in emissions as it occurs over time (i.e. the variation in difference between the two scenarios over time), including possible non-linear trends in baseline or project scenario emissions, which are illustrated by the curvature of the emission trajectories.

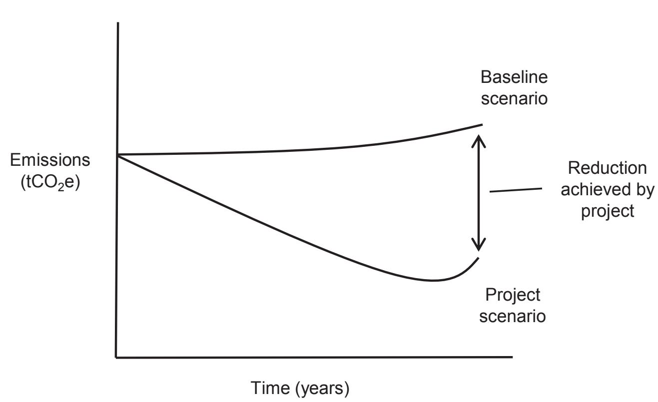

Fig. 1. Illustration of the key components of the project accounting method.

A third feature illustrated in Fig. 1 is that the calculation of change is done at an aggregate level, i.e. for the project as a whole, rather than at a normalised level per unit of activity or functional unit.

There are a number of other distinctive methodological features/concepts commonly associated with project accounting, which tend not to arise with the other consequential methods. These include *crediting baselines*, *conservativeness*, *emphasis on reductions*, *leakage*, and *additionality*. These are important to discuss in order to inform the analysis in Section 3.5 on whether these features constitute significant methodological differences or not.

3.3.1. Crediting baselines and conservativeness

Crediting baselines are intended to lie between the main estimated baseline and the project scenario, and are used to ensure that the number of credits issued by a project are not over-estimated, and hence are *conservative* (Trexler et al., 2006; Gustavsson et al., 2000). The prominence of these features in project accounting, but not in other consequential methods, can be viewed as a legacy of project accounting's development for crediting carbon offset projects. The credibility of carbon offsets may be undermined by over-crediting, and therefore many programmes build-in conservativeness to avoid this possibility.

3.3.2. Focus on reductions

Another legacy of carbon offsetting is the emphasis in project accounting standards on quantifying emission *reductions*, rather than *changes* in emissions more generally, i.e. increases *or* reductions. For instance, the *GHG Protocol for Project Accounting* states that the standard is intended for "quantifying and reporting GHG reductions" (WBCSD/WRI, 2005, p.5), and does not acknowledge the possibility of quantifying *increases* in emissions. However, the structure of the method is such that either reductions or increases in emissions could be measured; in the case of increases in emissions, the project scenario emissions line shown in Fig. 1 would be above, rather than below, the baseline.

3.3.3. Leakage

Leakage refers to emissions or removals caused by the project that occur outside the 'project boundary' (Vöhringer et al., 2006). However, the concept appears to be an artifice of identifying a 'project boundary'. If the aim of an assessment is to quantify the *total* change in emissions, i.e. both inside and outside the project boundary, then this is identical to simply quantifying *all* changes in emissions and dispensing with the idea of a 'project boundary' and 'leakage' altogether. Dispensing with the concepts of 'project boundaries' and 'leakage' is the approach taken by ISO 14064-2:

> Unlike the Kyoto mechanisms and other programmes, this part of ISO 14064 does not use the terms "project boundary" or "leakage". Instead, it refers to sources, sinks and reservoirs that are "relevant" to the project.
>
> ISO, 2006d, p.23.

Interestingly, there are some parallels between the concepts of 'project boundary' and 'leakage' on the one hand and the distinctions between 'foreground' and 'background' processes, and 'direct' and 'indirect' effects found in consequential LCA (Raadal et al., 2012; Searchinger et al., 2008). 'Foreground' processes are those that can be directly controlled by the entity undertaking the LCA, while 'background' processes are the other processes in the product's life cycle (Gaudreault et al., 2010). 'Direct' effects are those that occur in 'foreground' processes, and 'indirect' effects are those in 'background' processes (Raadal et al., 2012). However, as with project accounting, these distinctions in consequential LCA appear to be largely arbitrary, as all processes that change as a result of an entity's decision-making are subject to some degree of control (i.e. by definition they *change* as a result of the entity's decision-making). The distinctions also appear to be non-essential to the task of quantifying total change in emissions, as the same results would be achieved without using these distinctions. This is evidenced by the absence of these concepts in a number of consequential LCA studies, for example, Dalgaard et al. (2008); Schmidt (2008); and Schmidt and Weidema (2008). At most, the concepts of 'project boundary', 'leakage', 'foreground', 'background', 'direct effects', and 'indirect effects' can be viewed as presentational categories for grouping results into manageable components, but they do not appear to play a meaningful role in the actual quantification of change.

3.3.4. Additionality

A final concept that has been highly prominent in project accounting is that of *additionality* (Ascui, 2014; Stechemesser and Guenther, 2012), and it therefore also deserves some discussion. Despite the concept's prominence, it also remains an often poorly defined and misunderstood term. Gillenwater (2012) suggests that most of the definitions provided in the main project accounting standards, such the *GHG Protocol for Project Accounting*, *ISO 14062-2*, and *CDM*, are circular, i.e. projects are said to be 'additional' if they would not have occurred in a baseline scenario, and the 'baseline scenario' is in turn defined as being the absence of the project (Gillenwater, 2012). This is equivalent to saying the project would not have happened (i.e. would be additional) in the absence of the project. The root of the confusion is the conflation of two distinct pairings of cause–effect relationship: firstly, that between the policy intervention, e.g. the creation of a market for offset credits, and offset projects; and secondly, that between offset projects and the level of emissions they achieve. Fig. 2 is adapted from Gillenwater (2012) and illustrates this double-pairing of cause–effect relationships.

Gillenwater (2012) suggests that the question of additionality only arises for the first cause-effect pairing, i.e. projects are additional if they would not have occurred in the baseline scenario (with the baseline scenario defined as the absence of the policy intervention, and *not* in terms of the absence of the project). The circularity that Gillenwater identifies in many existing accounts of additionality arises because the project is treated as both the cause of the effect, and the effect that is being assessed for additionality.

Although Gillenwater's analysis does effectively diagnose and resolve the circularity evident in many proposed definitions of additionality it appears to be overly restrictive to proscribe that the concept can only be applied to the first cause-effect pairing (between a policy intervention and projects). It seems eminently possible to apply the concept of additionality to the second cause-effect pairing, and to ask whether the *level of emissions* achieved by a project is 'additional', i.e. would have been the same in the absence of the project. Furthermore, the concept of additionality appears to be a general one that can be applied to *any* cause-effect pairing, and is not restricted to the field of greenhouse gas accounting (e.g. 'Would my children have tidied their room (*the effect*) in the absence of me shouting at them (*the cause*)? Is their tidying additional to what would have happened in the absence of my action?'). The important point to take from Gillenwater's analysis is that the cause and effect in question cannot be the same thing, but the stipulation that additionality only applies to the relationship between offset markets and projects appears to be overly restrictive.

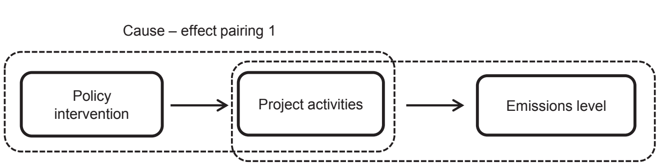

Fig. 2. Double-pairing of cause–effect relationships.

It is important to address the concept of additionality in the present discussion due to its prominence in the project accounting literature, however, the issue can also be viewed as something of a distraction from the core structure of the project accounting method. The core structure involves the quantification of baseline and project scenario emissions, and calculating the difference between the two (as shown in Fig. 1 and Equation (1)). The notion of additionality is already captured within that structure in the sense that if there is no difference between the two scenarios (i.e. if the two scenario lines in Fig. 1 are identical), there will be no 'additional' effect. Indeed, standards such as the *GHG Protocol for Project Accounting* largely side-step the issue of additionality in exactly this way, by treating it as implicit within the method: "Additionality is incorporated as an implicit part of the procedures used to estimate baseline emissions" (WBCSD/WRI, 2005, p.8). As with the concepts of *crediting baselines*, *conservativeness*, and *emphasis on reductions*, additionality can be seen as a legacy of project accounting's development within the practice of carbon offsetting, in which concerns about non-additionality arise.

3.4. Policy-level accounting

Policy-level greenhouse gas accounting aims to quantify the total changes in emissions and removals caused by policies, such as laws, regulations, taxation, incentive schemes, investment, information instruments etc. (WBCSD/WRI, 2013). Although there are many instances of policy greenhouse gas assessments (for example: Defra (2011); and US EPA (2013)), this field of practice has only recently undertaken the process of international standardisation, with the publication of the GHG Protocol's *Policy and Action Standard* in 2014 (WRI, 2014).

The structure adopted for policy accounting is essentially the same as that for project accounting, with the key steps involving the quantification of baseline and policy scenario emissions, and then calculating the difference between the two (WRI, 2014, p.9). The lack of a clear methodological demarcation between project and policy accounting may not be wholly unexpected given the lack of a clear demarcation between what counts as a 'project' and what counts as a 'policy'. Typically a project is characterised by physical activities in a specific geographic location (Watson et al., 2000, sec.5.1.2), while policies may involve less physical interventions such as regulations, taxes, and other market-based instruments. However, these distinguishing characteristics are not always present: projects can involve less physical interventions such as information campaigns, and policies can involve location-specific physical interventions, such as transport infrastructure. The lack of a clear demarcation means that there are likely to be interventions that could be assessed using either method, and it also suggests that these two forms of accounting could potentially be merged, or treated as sub-categories within an overarching generic framework.

Although the overall structure of project and policy accounting methods is essentially the same there are some areas of detail or emphasis that differ. One area that appears to receive greater attention in policy accounting is the possibility of interactions with other policies and actions. The *GHG Protocol Policy and Action Standard* identifies three types of relationship between policies (WRI, 2014, p.41): an independent relationship whereby policies do not affect each other; a reinforcing relationship whereby policies interact and increase their overall effectiveness (e.g. an awareness campaign

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and a subsidy may achieve greater change when implemented jointly than if they are implemented separately); and an overlapping or counteracting relationship, whereby policies interact and achieve less change than would be expected by summing what they would achieve individually. The main issue with reinforcing or overlapping relationships is that the results from individual policy assessments cannot be summed to estimate the total effect of implementing multiple policies, and if the *total* impact of interacting policies is of interest, then the interacting policies should be assessed together as a bundle (WRI, 2014, p.44). *Project* accounting is also able to accommodate interaction effects, by including interacting projects in the baseline or also assessing projects as a bundle, but the issue of interactions between interventions is not prominent in the project accounting literature, and is not explicitly addressed in *ISO 14064-2* or the *GHG Protocol for Project Accounting*.

Another possible area of slight divergence between project and policy accounting is in the use of 'direct' *change* calculations in policy accounting. So called 'direct' change calculations bypass the quantification of baseline and policy scenario emissions, and seemingly calculate the change in emissions directly (WRI, 2013). This method may be appropriate when total baseline and policy scenario emissions are unknown, but the change in activity, and therefore change in emissions, is known. For example, a transport policy may reduce vehicle mileage by two million miles per year, and in such a case it is not necessary to know what the baseline mileage is, i.e. whether it is 10 million or 20 million miles etc. However, the departure from the *baseline emissions − policy scenario emissions = change in emissions* structure (shown in Fig. 1 and Equation (1)) may be viewed as a largely superficial difference, as there is still an implicit baseline of '2 million miles more than the policy scenario'. In addition, the notion of '2 million fewer miles' appears to require the qualification of 'compared to the baseline', otherwise it is not known what the reduction relates to, i.e. it could be relative to 'last year', or 'country X' etc. An interesting issue is whether consequential LCA also involves implicit baselines, and this is explored further in Section 3.5.

3.5. Discussion

The previous sections outlined the main methodological features of each of the identified consequential greenhouse gas accounting methods, with some observations on the similarities and differences between them. The following discussion now provides a more in-depth analysis of the similarities and differences, which in turn provides a basis for critiquing the different methods and identifying opportunities for transposing lessons. The analysis also seeks to distinguish between features that represent fundamental divergences, and those that are largely superficial or non-essential.

One important difference between the methods is that project and policy accounting provide a time-series of impacts, i.e. impacts can be provided year-by-year or by any other unit of time, whereas consequential LCA only provides a single normalised impact figure which is intended to be valid for a broad period of time, typically the 'long run' (Weidema, 2003; Weidema et al., 2009). This treatment of time has a number of implications for the level of information provided by consequential LCA. Firstly, consequential LCA tends not to show short run impacts, and nor does it show the transition from short run impacts to long run impacts. This means that significantly different impacts from the short run product system may be overlooked if only a long run figure is provided.

Secondly, even when quantifying the impacts associated with the long run product system the temporal distribution of impacts *within* the product's life cycle tends not to be modelled in consequential LCA. However, the temporal distribution of emissions can be particularly important for understanding climate change impacts, as up-front emissions may not be equivalent to the compensatory avoidance of emissions later in the life cycle (O'Hare et al., 2009). This shortcoming is already largely recognised within the LCA community (ISO, 2006b; ISO, 2006a) and has given rise to the development of 'dynamic' LCA, which aims to include information on the temporal distribution of material and elementary flows (Levasseur et al., 2010; Collinge et al., 2012; Beloin-Saint-Pierre et al., 2014), which would align LCA with the time-series structure of project/policy accounting. Interestingly, although LCA appears to be playing catch-up in terms of developing a time-series structure, it may be ahead in developing temporally-explicit impact factors, such as temporally-adjusted global warming potentials (Levasseur et al., 2010), which do not appear to have been widely used in project or policy accounting. It is likely that the exchange of methodological lessons can work in both directions.

A further time-related issue for LCA, which is avoided by project/policy accounting, is the problem of how to deal with large non-linear emission events, such as land-use change or the production of capital equipment. As discussed earlier, LCA presents normalised results per functional unit, and it is therefore necessary to amortise or average large non-linear impacts over a period of time (Sjödin and Grönkvist, 2004; Hsu et al., 2010; Searchinger et al., 2008; Hertel et al., 2010). One major shortcoming with this approach is that the choice of amortisation period is largely arbitrary, for example, Searchinger et al. (2008) use an amortisation period of 30 years for the emissions from land conversion caused by biofuels, while the accounting rules for the EU Renewable Energy Directive use 20 years (European Parliament and Council of the European Union, 2009). In contrast, project/policy level accounting provides a time-series of emissions and removals, and therefore arbitrary amortisation periods are avoided.

Analysing change at the unit level can largely be seen as a legacy of attributional LCA, and there are a number of other problems that appear to come with it. Firstly, it is not always transparent what the aggregate scale of change is when the analysis is presented at the unit level. The existing guidance for consequential LCA guidance does state that the scale of the change should be identified (Weidema et al., 2009), however consequential LCA studies rarely provide a transparent statement of what the aggregate scale is (see for example Thomassen et al. (2008), or Dalgaard et al. (2008)). Relatedly, analysis at the unit level may have a greater likelihood of missing nonlinearities of scale or cumulative impacts (Hauschild, 2005), precisely because the analysis is not undertaken at the aggregate-level. Again, the existing guidance for consequential LCA does state that the scale of change should be accounted for, but it is nevertheless more likely that scale-effects will be missed due to the unit level of analysis. In addition, the question can be raised as to whether decision-makers will be better informed by understanding the aggregate impact that their individual decision is contributing to, particularly given that sustainability is a system-level property rather than a characteristic of individual practices (Gray, 2010). Project/policy level methods arguably achieve greater transparency, better inclusion of scale-effects, and also greater decision-usefulness by undertaking analysis at the aggregate level. Furthermore, unit level results can always be provided when it is useful to do so by dividing aggregate level results by the number of products produced, or by any other meaningful denominator (though the provisos above regarding nonlinearities of scale should always be kept in mind).

A different but equally important area of divergence between project/policy accounting and consequential LCA is that the former explicitly model baselines, whereas the latter does so only partially or implicitly. Any assessment of change always requires a baseline from which change is measured, and this is evident in some features of consequential LCA such as the procedure of substitution which involves identifying the product system that is displaced (i.e. the

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baseline) by the supply of co-products. The baseline and intervention scenario structure illustrated in Fig. 1 appears to have advantages in terms of increased transparency, but also has highly important benefits in terms of its conceptual robustness and the range of consequences it can accommodate. For instance, substitution is accommodated in LCA software and databases by treating the avoided product system as a negative input to the system studied (Weidema et al., 2009). However, this is conceptually awkward, in the sense that it is difficult to conceive of what a 'negative input' is. In contrast, with the baseline and intervention scenario structure the avoided product system can be accommodated in a conceptually straightforward way by including it in the baseline.

The baseline and intervention scenario structure is also able to accommodate consequences such as rebound effects and complementary products, which require ad hoc or additional procedures within consequential LCA (Weidema et al., 2009). The scenario structure is also able to model situations characterised by imperfect elasticity of supply in the long run, which is assumed not to occur in consequential LCA (Weidema et al., 2009). In terms of transposing lessons to consequential LCA, consideration should be given to adopting a baseline and intervention scenario structure.

The remaining features that tend to characterise one or other of the consequential methods represent largely superficial or non-essential differences. Project accounting is often characterised by the notions of *crediting baselines*, *conservativeness*, and an emphasis on *reductions*, *leakage* and *additionality*, but these are non-essential features that exist due to project accounting's development within the practice of carbon offsetting. *Additionality* in particular, where it relates to the cause-effect pairing of projects and emission levels, can be subsumed into the structure of the method itself and does not constitute a separate methodological step. Similarly, the concept of *leakage* is a largely superficial or presentational one which creates an arbitrary delineation between some impacts and others (as do the notions of foreground and background processes, and direct and indirect effects, in consequential LCA).

Some of the existing guidance for both consequential LCA (European Commission et al., 2010) and project accounting (ISO, 2006d) suggest that equal levels of functional output should be ensured when comparing scenarios. However, this also appears to be a non-essential requirement of either method as one of the consequences of a given decision could be an increase or decrease in the total functional output provided, i.e. our decisions do make us functionally better or worse off, and the total level of productivity is not always exogenous to the decision studied. A final superficial difference between the methods is that consequential LCA tends to be used for ex ante assessments, as its primary purpose is to inform decision making. However, as with project and policy accounting, it can be used for both ex ante appraisal or ex post evaluations of the change caused by past actions (Weidema, 2003).

A summary table of the main methodological features of each of the consequential methods, and the similarities and differences between them, is provided in the Appendix.

4. Conclusions

A first point to make is that the *three* identified consequential methods can be re-categorised as *two* different methods, as project and policy accounting are effectively the same approach. Recognition of this fact may have implications for how these two methods should be developed going forward, and raises the question of whether there should be a unifying process in which the two are integrated in future accounting standards. It is possible to envisage a single generic form of 'consequential time-series assessment', of which project and policy accounting are two possible two sub-types.

Building on the idea of a unified 'consequential time-series' method, a case can be made for developing consequential LCA as a further sub-type. The lessons that could be transposed from project/policy accounting to consequential LCA are the adoption of a time-series approach (as suggested by dynamic LCA), quantifying impacts at an aggregate level (with normalisation as a subsequent presentational option), and the adoption of a transparent baseline and decision scenario structure. The changes typically studied by consequential LCA, i.e. changes in product demand or configuration, could be straightforwardly characterised as the 'decision' or 'intervention' modelled by a unified 'consequential time-series' method, with the absence of the decision constituting the baseline. Interestingly, Plevin et al.'s (2014b) characterisation of consequential LCA includes a description of intervention and baseline scenarios (and the subtraction of one from the other to calculate change in emissions), even though this structure is only set out in the project/policy accounting literature, and is not present in the consequential LCA standards/guidance. It appears that some reconceptualisation or re-imagining of consequential LCA is already underway.

A further argument in favour of developing a unified 'consequential time-series' method is that there are likely to be cases that can be addressed using the times-series method, but which cannot be handled by consequential LCA, i.e. decisions/interventions that do not straightforwardly relate to products. For example, changes to income tax policy may have a general effect on economic activity and therefore impact on greenhouse gas emissions, but if it is not possible to identify specific product systems that are affected then the use of consequential LCA will not be appropriate. However, the reverse situation does not appear to arise, i.e. the flexibility of the time-series method means it can be applied to any product-related decision or intervention.

As an aside, it is interesting to note that the identified methodological shortcomings with consequential LCA can largely be seen as a legacy of its evolution from traditional attributional LCA, the structure of which does not include a time-series, aggregate-level quantification, or baselines. One is reminded of the traveller who asks for directions and is told 'I wouldn't start from here'. The same might be said of consequential LCA, given its attributional beginnings.

Nevertheless, the additional information and transparency from restructuring consequential LCA may come at the expense of ease of implementation or comprehensibility. This is something that could be explored in future research by applying the different consequential methods to the same case study scenarios in order to compare both the results *and* the practicality of implementation. Another consideration is whether additional information and transparency is actually required for fulfilling the goals and needs of the intended audience, i.e. there may be instances where a simplified approach is sufficient for the decision at hand. A final observation is that the process of comparing different greenhouse gas accounting methods appears to be a useful one for better understanding the nature of each method, and for identifying new avenues for methodological development. Similar benefits may also accrue from undertaking the same exercise with attributional greenhouse gas accounting methods.

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Appendix

Summary of the main methodological similarities and differences between consequential methods

Characteristics of method	Consequential LCA	Project accounting	Policy accounting
Key features			
1. Time-series of impacts	Consequential LCA generally does not show the distribution of impacts over time.	Project accounting generally shows the distribution of impacts over time.	Policy accounting generally shows the distribution of impacts over time.
2. Amortisation periods	Consequential LCA provides results per functional unit, and therefore large one-off emissions are amortised over a number of years. One disadvantage of this approach is that the amortisation period is largely arbitrary.	Project accounting does not have to use amortisation periods as emissions and removals are presented as a time-series.	Policy accounting does not have to use amortisation periods as emissions and removals are presented as a time-series.
3. Use of baselines	Consequential LCA does not explicitly use the concept of a baseline, though the concept is implicit in the measurement of change.	Project accounting is explicit in specifying a baseline.	Policy accounting is explicit in specifying a baseline.
Superficial features			
4. Crediting baselines, conservativeness, and emphasis on reductions	These features tend not to appear in consequential LCA.	These features often appear in project accounting and are a legacy of the method's development for carbon offsetting.	These features tend not to appear in policy accounting.
5. Additionality	Additionality is not referred to in consequential LCA, but it is implicit in the approach of only considering processes that change (i.e. processes that are additional).	Additionality is often referred to in project accounting, but can be subsumed or left implicit within the structure of calculating the difference between baseline and project scenario emissions.	Additionality is largely subsumed or left implicit within the structure of calculating the difference between baseline and project scenario emissions.
6. Leakage	The concept of leakage is not used in life cycle assessment, however, the distinctions between 'foreground' and 'background' processes, and 'direct' and 'indirect' effects are similar to that between 'in boundary' and 'out of boundary' effects (and therefore leakage).	The concept of leakage is used but is not essential to project accounting as it can be treated as an artifice of defining a project boundary. If all significant effects are quantified then the notions of a project boundary and leakage are not necessary.	The concept of leakage is generally not used in policy accounting.
7. Requirement for equal functional outputs in comparator scenarios	The comparison of different product systems generally requires the use of equivalent functional units. However, this is does not appear to be an essential requirement as one of the outcomes of a given decision may be an increase or decrease in functional output.	ISO 14064-2 requires that the project scenario should have the same level of product and service provision as the baseline scenario. However, changes in the level of product or service provision may be one of the consequences of implementing a project, and this requirement appears to be unnecessarily restrictive.	Policy accounting does not require the baseline and policy scenario to have equivalent levels of product or service provision, as one of the outcomes of a policy may be changes in the level of product or service provision.
8. Ex post or ex ante assessment	Consequential LCA is generally undertaken as an ex ante assessment, as it is primarily used to inform decision-making. However, the method can be used ex post to estimate the change caused by past decisions.	Project accounting can be used for either ex ante estimates of expected effects or ex post estimates for implemented projects.	Policy accounting can be used for either ex ante appraisal of proposed policies, or ex post evaluation of implemented policies.

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