Life-Cycle Assessment and Indirect Emission Reductions:

Issues Associated with Ownership and Trading

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May, 2003

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INTRODUCTION

There is an increasing interest in trading greenhouse gas (GHG) reductions associated with changes in the life-cycle emissions of certain products. We believe that such trading should be approached with great caution. This paper explains the need for concern, beginning with a Background section to provide an overview of life-cycle assessment, GHG registries and indirect emissions as they relate to product-based GHG accounting. The main body of the paper then outlines four categories of Concerns related to the practice. Conclusions are followed by a short glossary of terms used in the field.

BACKGROUND

Life-cycle Assessment

Manufacturers, consumers and public policymakers are beginning to examine the full environmental impacts of products over their entire life cycles, from raw material acquisition to manufacture, distribution, use and, ultimately, disposal. Life-cycle assessment (LCA) is a tool that has been used to evaluate the full impacts of alternative manufacturing practices or to encourage environmentally sensitive design. For example, a company producing products that generate their own emissions when used – like automobiles – may change the design of the product in a way that substantially reduces its environmental impact. In this case, LCA serves as a tool to identify and quantify environmentally superior products or practices and to support responsible procurement policies.

Increasingly however, LCA is gaining favor as a policymaking tool, especially to encourage reductions of greenhouse gas (GHG) emissions. In the context of climate change accounting and greenhouse gas measurement, LCA can point to opportunities to reduce the demand on emissions-generating activities related to a particular product, even when those activities lie outside the product manufacturer's corporate boundary. The term *indirect emissions* has been coined to refer to those emissions that result as a consequence of one entity's actions but that are emitted from sources owned or controlled by another entity. In this context, LCA is essentially a tool used to calculate indirect emissions.

This paper takes a close look at the unique challenges and problems confronting the use of LCA as a policy tool to support emissions reductions, with special emphasis on the issues associated with indirect emissions trading in the absence of a regulatory cap and trade system.

GHG Registries

Many states in the US are setting up emission registries to encourage early, voluntary actions by companies to reduce their GHG emissions and most are implicitly or explicitly endorsing the use of LCA and indirect emissions accounting.

Although these vary in their scope and function, they share several essential elements. At its most basic level, a registry provides a central, independent repository for credible information about emissions activities. Most state registries currently are only designed to allow for public reporting, but as markets develop for tradable reductions, a broad spectrum of market participants will turn to registries to provide the infrastructure to support a robust market.

A basic registry offers an opportunity for companies to voluntarily report emissions data in advance of a mandatory program. But the role of a registry in an emissions trading system goes well beyond documenting annual emissions. It performs a critical data management and accounting role and serves as a ledger of all transactions. Perhaps more importantly, by setting strict standards for the quality of information it accepts, the registry system helps ensure the quality of the entire emissions management system. In short, the registry helps establish claim or title to emissions and reductions. Even registries that are not currently established to support trading are setting precedents by supporting reporters who seek to make a claim of ownership over indirect emission reductions that occurred outside their boundaries.

Indirect emissions trading

Many state registries require reporting on indirect emissions, which often serve an important part of a company's voluntary efforts to reduce emissions. These reductions in indirect emissions are often used to count as progress towards internal targets. However, as indirect emissions continue to grow in importance, increasing pressure will be applied to allow these reductions to be traded in open emission markets. Demand for tradable, fungible emission reductions will require assessment of the unique properties of indirect emissions as a tradable commodity. Trading indirect emission reductions requires elaborate and difficult policymaking. It is our view that indirect emissions trading will only be credible if the following concerns are adequately addressed:

1. Insufficient Accuracy/Consistency
2. Ownership and Multiple Counting
3. Cherry Picking
4. Complexity & High Transaction Costs

CONCERN #1: INSUFFICIENT ACCURACY/CONSISTENCY

A healthy emission trading market requires rigorous and consistently enforced accounting standards that ensure the fungibility of all emissions or reductions being traded. In a capped system the unit of trade is an allowance, which is created by a regulatory body and used to offset direct emissions. In an uncapped system the commodity being traded is a potential credit or verified emission reduction (VER). Effective VER markets are extremely difficult to create because of the ambiguity of accounting schemes, and the differences between the two most common ways to calculate reductions:

- Reductions calculated relative to a historic data point (i.e., base year emissions)
- Reductions calculated relative to a project-specific business-as-usual (BAU) trajectory.

Developing baselines and verifying trends of direct emissions is a difficult task for many companies even when data are readily available, but for indirect emissions calculations these tasks are even more difficult. Establishing a BAU trajectory requires answering the hypothetical question “what would have happened in the absence of this project or activity?” Setting counterfactual emissions baselines and attempting to prove the additionally of each VER provides a very weak basis for the numeric (tradable) value of each VER.

The Environmental Law Institute (ELI) recently concluded in a comprehensive study of existing NO_x discrete emission reduction markets (ELI 2002):

> “...credit trading programs by themselves have inherently weak environmental integrity. Because states have not found objective tests for additionality of credit-generating projects, emissions credit systems are “leaky,” and hence may provide credit for reductions that sources would have made anyway.”

This inherently weak environmental integrity is compounded further when one looks toward LCA for identifying VERs outside the corporate boundary. While LCA is gaining respect as an important field of study, and methodologies are evolving quickly, there are still significant disagreements among practitioners about aspects of LCA practice that can affect results significantly.[1] In particular, system boundaries – which process paths are being evaluated, and how deeply – are unstandardized and can affect the results of a life-cycle inventory (LCI) not just by a few percent, but by entire multiples. Because of the lack of standardization of methodology, LCI’s are usually only valuable for choosing between products (or processes), when those products are evaluated by the same researchers, using identical system boundaries and allocation rules.[2] There is typically little comparability between independent works. As a result, an indirect VER claimed by one reporter, based on particular process paths evaluated to a certain depth, may have a different value according to an entity asserting that some of those process paths should not be in the system boundary, or should be evaluated less deeply.

Limitations of Upstream Data

In the United States, the vast majority of GHG’s are generated in the process of burning fossil fuels to generate energy. Hence, projects affecting energy delivery (typically electricity) would be a prime target for VER’s. However, most electricity is delivered to final consumers via a grid that supports a large and varied spectrum of electricity generators, varying on a daily and hourly basis. Furthermore, electricity supply in a given region is “wheeled” to and from other regions meaning that, in the end, the source of electricity delivered to a particular customer, at a particular time, is usually unknowable. Instead, complex models are used to *estimate* what the mix of electric generators supplying the customer may have been at a given time, meaning that VER’s based on reduction of electricity are not equivalent to any directly measurable quantity. In fact, a common approach to calculating the effectiveness of an indirect energy efficiency project is to measure electricity savings and convert to emissions reductions on the basis of a grid-average or state-average displacement rate (lbs CO2/kW). Often

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[1] The documents closest to governing LCA practice are the Society for Environmental Toxicology and Chemistry’s (SETAC) *A Technical Framework for Life-Cycle Assessment* and the International Standards Organization (ISO) 14040-series standards. Even these do not set specific methodologies for dealing with fundamental issues of LCA such as setting system boundaries or allocating factory outputs.

[2] Allocation rules govern how the material and energy inputs to a factory, are allocated among the various products output by the factory.

this factor is an annual average which may not accurately reflect the actual impact of the reduction in electricity at that project, at that time. Two examples are provided to illustrate the inherent inaccuracy of upstream calculations.

Example 1: Energy efficiency improvements by a manufacturer who purchases fossil-fuel generated electricity. In this case total annual electricity use is reduced and the reduction in electricity use can be measured but the question remains "What happens to up-stream emissions?" Logically, one can expect that emissions were reduced but actually verifying where and how much is a nontrivial exercise requiring access to confidential dispatch data.

In fact, emissions may not have decreased at all. If local electricity demand rises despite these energy efficiency improvements then power plant emissions will rise as well. This is exactly the case nationwide over the last 10 years where emissions from electricity generation continue to increase despite numerous documented energy efficiency projects. This distinction is especially important to the current voluntary emission reduction trading markets. Buyers of emission reductions are often unwilling to equate avoided growth to actual reductions in direct emissions measured against a base year level. One of the reasons buyers are reluctant to purchase indirect emissions reductions is the problem of inaccuracy in quantification. This problem of insufficient accuracy in determining which efficiency project results in reductions and which results in avoided growth is unique to indirect emissions calculations. The technical problem could be solved by fiat if an authority could set policy and establish rules and procedures for applying an acceptable displacement rate and assigning ownership but this is unlikely in a voluntary open market.

Example 2. Green power production by a windmill operator whose power production is displacing fossil fuel-generated electricity. In this case, again, we have the question – were emissions actually reduced at any of the local power plants, and if so, by how much? Again, the technical analysis and effort to verify reductions requires information about upstream operations that may be difficult to acquire. Estimates can be made based on average or marginal displacement factors but actual measurement of reductions are difficult to verify.

Where a corporation looks to other material inputs to generate upstream emission reductions, there will be substantial barriers to obtaining sufficiently accurate data – for example, (1) the corporation's suppliers may be unwilling to provide the proprietary energy and materials inputs data necessary to establish GHG's associated with the supplied materials; (2) the suppliers may simply not track all the data necessary;[3] (3) the suppliers may substitute specification-equivalent products that are not GHG-equivalent; (4) the corporation may buy from multiple suppliers, changing suppliers as economics dictate; (5) GHG's emitted in transportation of the materials may vary depending on delivery methods and distances, further complicating the analysis.

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[3] One aspect of this problem is particularly ubiquitous among LCA's, and is known as the *allocation* problem. Most factories produce an entire spectrum of products, but energy and raw materials are purchased in bulk on single invoices, and there is no motivation to meter the distribution of the energy and materials among the various products. If a corporation is attempting to create an upstream DER related to a certain supplied product, it is more likely than not physically impossible to allocate the supplier's GHG's to the specific product. Methodologies exist for estimating the allocation of emissions to product outputs, but they do not permit actual measurement of the emissions.

Limitations of Downstream Data

Most downstream emission reduction claims are related to the use-phase of a product. Any product that is manufactured in large volumes and distributed widely to many, dispersed users is virtually guaranteed to allow only estimates, and not verifiable measurements, of GHG emissions related to its use.

Imagine for instance that an appliance manufacturer wishes to generate downstream emission reductions from a high-efficiency washing machine. Each washing machine owner will operate the machine on different settings, install the machine on a different electric grid, use the machine at different times of the day, use the machine more or less frequently, and discard the machine sooner or later. The appliance manufacturer can do no better than to *estimate* all of these variables, based on user surveys or other imprecise studies.[4]

As in the case with upstream emissions, a policy solution to this problem of uncertainty is required since technical solutions have inherent problems due to lack of access to required data. For example, in the United Kingdom emissions trading system policy direction has provided a fixed electricity emissions displacement factor that allows consumers to generate credible reductions purely from end use efficiency projects. The producers are given an incentive through renewable certificates. Although the actual emission reductions may not be measurable, by fiat the correct quantity of emission reductions is determined by use of a common factor established by policy.

CONCERN #2: OWNERSHIP AND MULTIPLE COUNTING

The underlying framework of any trading schema is ownership: you can't trade what you don't own. It is the role of greenhouse gas registries to set the parameters that define initial ownership of each VER created.

Traditionally, it is understood that the owner of a facility owns the emissions that emanate from it. This is clearly illustrated through the U.S. EPA's acid rain trading program, in which sulfur dioxide allowances are allotted to, and traded among, electric generators that emit sulfur dioxide. It is not the coal suppliers that are held responsible for the sulfur in their coal. Neither are the electric utilities' customers held responsible for the sulfur dioxide emissions caused by the electricity they purchase.

In another example, the owner of every automobile is held responsible under mobile source provisions of the Clean Air Act for their own tailpipe emissions. Though standards exist for design emissions from each model marketed by an automaker, once an individual purchases each vehicle and burns gasoline in it, it is their and only their responsibility to meet emissions standards. When an individual's car fails the emissions

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[4] The example in the text is further complicated by the fact that all of the emissions associated with the homeowners' use of the washing machine would be from generation of electricity, thus burdened by all of the limitations of *upstream* data. A more simplified example would be a fuel-efficient automobile, for which the related emissions would be directly attributable to the consumer-user. Even in this case, though, the actual emissions savings would depend upon a variety of user-specific variables – fuel used, driving habits, climate and road conditions, and auto maintenance – which could only be estimated at best.

test we don't hold gasoline manufacturers responsible for carbon monoxide emissions, or the vehicle's engine manufacturer responsible for elevated NO_x levels.

In both examples, and many others, the common theme is that the *owner of the emitting facility (whether stationary or mobile) is responsible for its associated emissions.*

Looking to a product's life-cycle for VER's is *by definition* attempting to secure ownership of emissions reductions that occur outside the corporation's own facilities. This has three interesting consequences: (1) multiple claims on ownership can occur, (2) baseline emissions must be established before reductions can be claimed and (3) the corporation holds full responsibility for emissions outside their own facilities.

Multiple Counting

Imagine that an aluminum manufacturer embarks on an initiative to intensively market their product to major automobile manufacturers, with the intent that the aluminum manufacturer can claim estimated emissions reductions from the lighter, more fuel-efficient vehicles that result. Now suppose that one of the automobile manufacturers enthusiastically buys into the aluminum manufacturer's initiative and aggressively markets the new, lighter cars to consumers and therefore also claiming estimated emissions reductions from the new vehicles. Lastly, imagine an environmentally concerned consumer who is tracking her annual carbon dioxide emissions.[5] She decides to replace her current car with a new, lighter vehicle and understands that she has contributed to reducing her contribution to greenhouse gases by an equivalent amount. Now all three parties have taken claim to the emissions reduction, when in fact only the ultimate car owner is the legitimate owner of the emissions reduction, per our traditional understanding of emissions responsibility described above.

A credible market for trading GHG VER's obviously cannot allow multiple claims to the same emissions reduction. One obvious tool for solving this problem is contractual assignment of ownership.[6] In the example above, if the automaker is to sell VER's based on the lighter vehicles, then each time a consumer purchases a car they must be given the option to sign a contract with the automaker assigning the automaker ownership of (a part of) GHG emissions attributable to the vehicle's presumed use by its owner. If the aluminum manufacturer is to claim the VER's, then *in addition* to the contracts with the end-users, the automaker will need to sign a contract reassigning ownership of (a part of) the GHG's a second time, to the aluminum manufacturer.

Baseline must be set first

Returning to the automotive example: Initiating contractual ownership with car buyers is equivalent to expanding the corporation's system boundary for GHG inventories. A

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5 A number of such enthusiastic consumers do exist. See for instance, the list of websites to support this that is provided by the EPA at
yosemite.epa.gov/oar/globalwarming.nsf/content/
ResourceCenterToolsCalculators.html?OpenDocument#Individuals

6 Electricity is the only industry in which emissions ownership has been explicitly addressed. For instance, a recent article in Environmental Finance (Burnett & Ashford 2002) proposes a methodology guiding electric generators and their customers in sharing ownership of emissions associated with electric generation.

reduction in those emissions cannot occur until there is a multi-year record of the emissions in that system boundary. This is equivalent to the setting of a baseline year as described in the GHG Protocol and in most other published GHG accounting procedures. A serious methodological problem arises, however, when considering that each consumer can, and typically does, purchase automobiles from a variety of manufacturers. Even if a given automaker can demonstrate that the emissions attributable to *their* average car buyer is decreasing, this means nothing about trends in the emissions attributable *to the car buyers themselves*. Possible solutions to this problem are (1) to compare trends in emissions attributable to their average car buyer to trends in emissions attributable to a national average car buyer or (2) to track only emissions from brand-loyal car buyers.

Responsibility of ownership

In an open market that includes indirect VER's, each registry is responsible for setting rules that allow the calculation of a VER resulting from reduction of upstream or downstream emissions related to a particular product. Presuming contractual ownership has been properly addressed as above, the reduction itself is treated as an object having positive value. But the VER has a positive value only because the VER's buyer understands GHG's themselves to have a *negative* value. Differences in perceived negative value of GHG's drive the current, voluntary market, but eventually stronger regulatory systems will assign a negative value to *all* GHG emissions. This will cause a problem for claimants of indirect VER's.

To see why, let's return to the automobile example. Assume that an automaker has taken contractual ownership of its customers' GHG emissions. Presumably, a capped market will assign allocations to each manufacturer in the traditional method, based on emissions due to their facilities. But the automaker owns considerably more emissions than this due to their assignment contracts, and will need to offset emissions that greatly exceed their allocation. A potential solution to this problem may lie in flexible contract mechanisms that allow ownership of emissions to return to the car owner when a closed market is implemented, or in contracts that assign presumed emissions *reductions* without assigning the emissions themselves. However, either of these solutions is ethically dubious, and begs questions of opportunism.

CONCERN #3: CHERRY PICKING

Cherry picking system boundaries

Many advocates of using LCA to measure discrete emissions reductions focus on one product or process and one particular path, upstream or downstream, for assessing the reduced emissions impact. The obvious risk of such a piecemeal approach is that reporters have significant incentives to cherry-pick their reported reduction projects, with no responsibility to demonstrate all projects have been reported on, or that an *entire* product's life-cycle emissions are decreasing.

Relatively innocent cherry picking can also evolve into deliberate gaming of the system. A proper LCA may examine hundreds of process paths to identify those select few that meet a certain minimum significance in the product's total inventory. Because each corporation that is attempting to create VER's will be the most expert in the life-cycle of its own products, the corporation has a distinct advantage in being able to argue which paths are the important ones, and obfuscating the reasons therefore.

The corporation can turn this advantage toward choosing and reporting LCA data only on those paths that offer easy opportunity for *reductions*, rather than those that constitute the bulk of the full LCA. Or it can hide GHG-intensive paths from other parties by failing to include them in the full LCA, thus magnifying the apparent, relative reductions in the remaining paths.

The solution to this type of cherry-picking is to set concrete standards for LCA boundary-setting. Though this solution is straightforward and likely to be effective, it is a massive undertaking. The quantity of work that has already gone into the special case of electricity generation is a perfect example of this: the effort to create standard system boundaries for any given product class (industry) will be equal to what we have already witnessed to take place for understanding the upstream emissions profiles of electricity.

<u>Cherry picking products</u>

This tendency to cherry-pick particular projects (or products) under a voluntary reporting system is quantitatively documented in the context of the federal government's 1605(b) voluntary GHG emissions registry. The 1605(b) registry allows the reporting of either entity-wide emissions, project-based emissions, or both. A 2001 report by the Natural Resources Defense Council (Lashof 2001) demonstrated that the 1605(b) registry has been overwhelmingly used to selectively report impressive project-based reductions, while allowing industry emissions to increase per business as usual:

> Under 1605(b), companies are able to report emissions "reductions" from one set of activities, while ignoring other activities that increase emissions. For example, Duke Energy reports significant emissions "reductions" associated with increased generation at three of its nuclear power plants, but the company recorded an overall emission increase from its fossil generation fleet of over 26 percent between 1990 and 1999. None of the emissions increases were reported as projects or counted against claimed "reductions." Similarly, Baltimore Gas & Electric reported "reductions" associated with heat rate improvements at three fossil fuel power plants in 1999, but emissions from its fleet increased 50 percent between 1990 and 1999. Allowing for reporting of "reductions" from one set of operations, and simultaneously ignoring emissions increases from other activities is a significant accounting loophole in the 1605(b) program. To achieve real emissions reductions, programs must clearly account for all emissions activities.

Unlike cherry picking of system boundaries, cherry picking of products does not threaten the integrity of LC-based VER's *per se*. Rather, it is a basic ethical concern regarding the choice to trade product life-cycle-based reduction credits. In theory, taking responsibility for product life-cycle is taking responsibility for environmental impacts outside one's own corporate boundary, a very magnanimous action. What a tremendous irony, then, that by cherry picking certain products a company can make itself appear very environmentally conscientious to the extent of looking outside of its corporate boundary, when in fact it has *precisely failed* to take responsibility for the most basic emissions inventory, its own corporate boundary. The solution to this concern lies in the hands of environmental advocates. Environmental advocates must understand that the existence of life-cycle based VER's generated by an entity, no matter how impressive, say nothing about the entity's true environmental responsibility, unless (1) *the entity's corporate inventory is openly reported and well-managed* and (2) *the corporation submits its entire product portfolio to LCA*.

Cherry picking pollutants

The choice to claim reductions of GHG's without accounting for the effects of other pollutants is another form of cherry picking. For example, imagine a manufacturer of a gasoline additive that slightly increases average fuel economy seeks to take credit for the associated GHG emission reductions realized in individual automobiles. If it is subsequently discovered that the additive results in increased nitrogen oxide emissions in certain types of vehicles, will the manufacturer claiming the GHG emissions reductions be required to offset the NO_x emissions from automobiles operating in NO_x-regulated environments? Solutions to this problem, and the problem itself, are similar to the issue of future designation of GHG's as a negative-valued pollutant. The solutions are most likely contractual arrangements isolating the manufacturer from collateral pollutants. Indeed, the choice to claim a positive value from an emissions reduction without taking responsibility for the gross emissions to begin with may be the ultimate form of cherry picking.

CONCERN #4: COMPLEXITY & HIGH TRANSACTION COSTS

The life-cycle emissions of a product or process beyond a given corporate boundary can involve hundreds, even thousands, of process paths. Standardizing the system boundaries and factory allocation methodologies, separately for each product class, taken together with the problems related to ownership and cherry picking, means any contractual or regulatory system designed to accommodate product life-cycle accounting and trading of GHG emissions will be burdened by extensive complexity and high transactions costs.

In conventional emissions inventories, the corporate boundary provides a neat and *de facto* boundary for accounting process paths and their associated emissions. Trading emissions that lie outside the corporate boundary will require a *de jure* (regulatory) determination of the boundaries for accounting process paths. Legislation and rulemaking becomes a balance between scientific accuracy and the relative political influences of the various stakeholders. This is a problem already well-known in the world of project-based emission credits (*e.g.* CDM), in the form of negotiations to define baselines, additionality, leakage and permanence.

Because the academic LCA community makes no uniform statements about system boundaries, such negotiations will be even less established in science or practice,[7] and even more influenced by political interests. Negotiations will have to be carefully controlled to handle the additional concerns associated with ownership and cherry picking, as well.

At least two organized efforts to establish GHG accounting principles based upon life-cycle assessment have foundered on the complexity of the undertaking. In 1998, the

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[7] The same problem arises with respect to allocation, as discussed in footnote 3.

World Business Council for Sustainable Development (WBCSD) and the World Resources Institute (WRI) convened an effort to create a worldwide standard for corporate GHG accounting. Until January 2002, the draft standard was to include a module on "Value Chain" accounting, but the endeavor, which included a wide range of participants from industry, government and non-profit organizations, was abandoned (WBCSD/WRI 2002, Bhatia 2002)). Even a remaining effort to continue developing only the use-phase standards for the automotive industry was recently abandoned due to lack of support from the automotive sector businesses. Similarly, the Intergovernmental Panel on Climate Change (IPCC) attempted in 1996 to create life-cycle assessment procedures to account for wood products as they made their way from raw material to final product. That effort, too, was abandoned

Clearly, any legislative or regulatory attempt to create a system for accounting GHG emissions reductions on the basis of LCA, will be unavoidably complex. Similarly, if private entities endeavor to assign the rights to indirect VERs by contract, the contractual terms will be complex and the necessary disclosures to permit due diligence and independent verification will be invasive.

CONCLUSION

As noted at the outset, LCA is a valuable tool for comparing the relative environmental impacts of two or more products or processes. It may thus be a useful means to distinguish products, for example, by "green" labeling – in the context of GHG emissions accounting, the Climate Neutral Network has established just such a labeling system for products. It may also be a useful instrument for policymakers to apply in developing appropriate incentives to encourage GHG-sensitive product design, manufacture, selection/use and disposition. Certainly, companies should be encouraged to apply LCA methods to all of their products and processes, to document the results and improve the measurement methodologies, as well as the products and processes themselves.

Because of the problems of inaccurate and inconsistent measurement, double counting, cherry picking and overall complexity, indirect VER's identified with a product life-cycle are unlikely to be viable trading instruments in an open emissions trading market. Though such VER's may be somewhat more viable in a closed market (*e.g.* through the use of set-asides), most barriers to their fungibility would apply in any market. Clear policy guidance on the use of displacement factors would not guarantee accuracy but would at least establish consistency in this area.

GLOSSARY

The following definitions include some terms that are commonly used in the GHG accounting community, but that are not used in the text of this paper. These are included among the definitions in order to clarify their *relationships* to the terms we do use here, which are indicated by ***italic boldface*** type.

closed market – an emissions trading market in which the market's regulator controls the total quantity of emissions reductions or allowances available to the market.

direct emissions – Emissions from sources that are owned or controlled by the reporting company.[8]

***downstream* emissions** – *Indirect emissions* occurring after a reporting company has sold or otherwise relinquished ownership of a particular product.

indirect emissions – Emissions that are a consequence of the activities of the reporting company, but occur from sources owned or controlled by another company.

indirect VER - A *VER* derived from reductions in *upstream emissions* or *downstream emissions*.

life-cycle – Consecutive and interlinked stages of a product system, from raw material acquisition or generation of natural resources to the final disposal.[9]

life-cycle assessment (LCA) – Compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its *life cycle*.[10]

life-cycle inventory analysis (LCI) – Phase of *life-cycle assessment* involving the compilation and quantification of inputs and outputs, for a given product system throughout its *life-cycle*.

open market – an emissions trading market in which the total quantity of emissions reductions or allowances available to the market is indeterminate.

reporter – An entity that is reporting a GHG inventory and/or *VER's*. Synonymous with "reporting company" as used in the WBCSD/WRI GHG Protocol.

Scope 1 emissions – A reporting organization's *direct* GHG *emissions*.[11]

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[8] The definitions of direct emissions and indirect emissions are copied verbatim from the WBCSD/WRI GHG Protocol glossary (WBCSD/WRI 2001).

[9] The definitions of Life Cycle, LCA and LCI are copied verbatim from ISO 14040:1997(E) (ISO 2001).

[10] It is customary to break LCA into two components: life-cycle inventory (LCI) and life-cycle impact assessment (LCIA). The latter is the practice of weighting and evaluating the results of an LCI to determine their overall impact on the environment, according to stated assumptions about the social and environmental values of the LCA's audience. Since in this paper we are concerned with specific issues relating to greenhouse gas (GHG) *inventories*, the particular environmental impacts of GHG emissions are not at issue. Thus in the context of this paper, one may think of the term "LCA" as synonymous with "LCI," signifying only the life-cycle inventory component of the process.

Scope 2 emissions – A reporting organization's emissions from imports of electricity, heat, or stream.

Scope 3 emissions – A reporting organization's *indirect emissions* other than those covered in *Scope 2*.

upstream emissions – *Indirect emissions* occurring before a reporter has purchased or otherwise achieved ownership of a particular product, or the inputs to the product.

value chain – Synonymous with *life-cycle*.[12]

verified emission reduction (VER) – A quantity of emissions sequestered, neutralized or avoided, verified for the purpose of being fungible in an emissions market.

[11] The definitions of Scope 1, Scope 2 and Scope 3 are copied verbatim from the WBCSD/WRI Greenhouse Gas Protocol. Note that Scope 2 emissions are a special case of upstream emissions. Any *other* upstream emissions, plus *any* downstream emissions, are Scope 3 emissions.

[12] In June of 2001 the WBCSD/WRI GHG Protocol developers adopted the term *value chain* in lieu of *life-cycle* (Norris 2001). Though WRI/WBCSD chose the term to avoid abusing the terms of art extant in the LCA field, we discourage the use of *value chain* precisely because an effort to consider a product's entire life-cycle should be subject to the concerns associated with formal LCA practice, as we argue in this paper.

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