Letter to the Editor

The Use of Life Cycle Assessment in the Support of Robust (Climate) Policy Making: Comment on "Using Attributional Life Cycle Assessment to Estimate Climate-Change Mitigation . . . "

The arguments of Plevin and colleagues (2014, 73) center on the assertion that "because of several simplifications inherent in ALCA [attributional life cycle assessment], the method, in fact, is not predictive of real-world impacts on climate change, and hence the usual quantitative interpretation of ALCA results is not valid. A conceptually superior approach, consequential LCA (CLCA), avoids many of the limitations of ALCA, but because it is meant to model actual changes in the real world, CLCA results are scenario dependent and uncertain. These limitations mean that even the best practical CLCAs cannot produce definitive quantitative estimates of actual environmental outcomes." Plevin and coworkers conclude that both approaches[1] yield valuable insights, but that only CLCA can support robust decision making, so that policies implemented are less likely to have perverse effects.

Although mostly agreeing with Plevin and colleagues (2014), we argue that some of the limitations ascribed to ALCA also affect many other modeling approaches, including CLCA. We support the notion that CLCA is more appropriate than ALCA in informing policy development because it addresses indirect effects, such as substitution and rebound effects, but maintain that there are some types of analysis for which ALCA may be appropriate.

On Missing Climate-Change Impacts

Plevin and colleagues (2014) mention the ongoing debate over metrics for quantifying climate-change effects, but are not explicit in describing the issue. A particular deficiency of conventional life cycle assessment (LCA), attributional or consequential, is that it ignores, or deals crudely, with the time dimension and thus gives equal weight to emissions occurring today or in 99 years' time. Some methods ignore emissions after 100 years, whereas others give equal weight to emissions regardless of when they occur. There is considerable literature debating the best way to account for the climate impacts of biogenic carbon fluxes and their timing, but still this issue is far from being resolved (Brandão et al. 2013). Whereas complex scientific research informs the development of climate metrics, we agree with Plevin and coworkers that the choice of metric is subjective.

On Uncertainty in Deterministic Models

Both ACLA and CLCA are subject to uncertainty, with respect to accuracy and precision. Accuracy relates to representativity, which is a form of epistemological or scenario uncertainty, and precision to statistical uncertainty (see figure 1). The principal reason that consequential models, used, for example, for assessing the potential to mitigate climate change, are more robust than their attributional counterparts is because the system changes modeled are more complete, which inevitably increases scenario uncertainty. But, is CLCA really more uncertain?

As pointed out by Weidema (2009), the exclusion of displacements in ALCA does not diminish the uncertainty, but rather conceals it. Neglecting indirect effects, such as those arising from substitution effects, does not reduce scenario uncertainty, even if statistical uncertainty is reduced. In this sense, ALCA can be said to be more precise, but CLCA more accurate, meaning the ALCA results may be biased and CLCA results imprecise. Though CLCA may be less precise, it is not necessarily less certain, a point missed by Plevin and colleagues (2014). We leave it to the reader to decide whether precision or accuracy is preferable in a particular instance, but point out the maxim in decision making, "It is better to be vaguely right than exactly wrong" (Read 1898, 272).

Much of the uncertainty attributed to CLCA is derived from assumptions of what the sources of (marginal) supply are. Modeling multiple scenarios to reflect alternative supplies in CLCA may be time-consuming, but the value of the study will be enhanced if different scenarios are explored. Including multiple scenarios is also a way of minimizing and quantifying uncertainty from the choice of marginal supply. These choices can be based upon expert opinions in a participatory approach (see below). Plevin and colleagues (2014) argue that LCAs that use system expansion when dealing with multifunctional processes give results that are too uncertain to support robust decisions. However, we do not see system expansion as a distinct issue; in CLCA, system expansion is one aspect of scenario uncertainty (see the Supporting Information available on the Journal's website).

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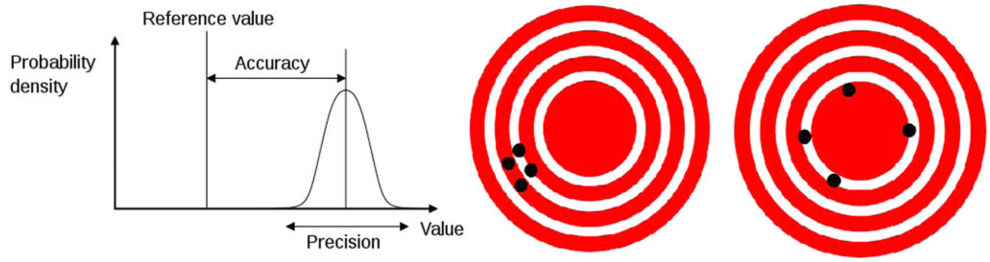

Figure 1 Illustration of the concepts of precision and accuracy (EC 2010). Precision refers to variability (i.e., deviation around the mean), whereas accuracy refers to distance from a reference (true) value. The true value is, in most cases, unknown, which makes this scenario uncertainty (known unknown) difficult to determine. The left target shows a case with high scenario uncertainty and low statistical uncertainty (i.e., high precision), whereas the right target shows a case of low scenario uncertainty and low precision (i.e., high statistical uncertainty).

On Economic Partial- and General-Equilibrium Models

CLCA requires a way to estimate the consequential effects of system changes. A few studies have used economic-equilibrium models to implement CLCA (see Kløverpris et al. 2008; Dandres et al. 2012; Vázquez-Rowe et al. 2014). As with all models, equilibrium models are simplifications of reality and therefore are subject to similar limitations to other modeling approaches, including ALCA and CLCA (see, e.g., Krey 2014). Because ALCA is not concerned with changes in demand or with indirect effects in product systems, only the CLCA approach is appropriate for combining with economic-equilibrium models (e.g., Earles et al. 2013).

There is a fundamental issue in combining computable general equilibrium (CGE) and partial equilibrium (PE) models with CLCA. Biophysical CLCA and CLCA based on economic equilibrium models differ in the way they represent changes in the system. Unlike biophysical CLCA, CGE and PE models do not assume perfect substitution, enabling them to estimate changes in production and consumption in response to price changes by including elasticities of supply and demand. Economic equilibrium models use assumptions on price elasticities to account for the size of system changes in response to policy "shocks," for example, when assessing the effects on food security resulting from food-price rises from increased demand for biofuels. Biophysical CLCA typically models an increase in demand for the product, which is the focus of the study *ceteris paribus* (i.e., while assuming constant supply and demand of all other products, rather than using price elasticities[2]). By taking into account price elasticities, it is possible to determine the extent to which product A is likely to substitute product B, but the use of nonempirically based price elasticities is an additional source of scenario uncertainty.

Concluding Remarks: On the Role of Life Cycle Assessment in Decision Making

Essentially, all models are wrong, but some are useful (Box and Draper 1987, 424).

Consequential modeling of, for example, biofuels and indirect land-use change (iLUC) provides insight into a complex system that is not captured by ALCAs, which ignore the fact that background systems are important in an interlinked global economy (e.g., Brandão 2012).

Further, including indirect impacts is not only compatible with, but even inherent to, the philosophy in LCA of not shifting burdens between different life cycle stages, impact categories, product systems, regions, and between direct and indirect impacts. Nonshifting of burdens ensures that improvements in one impact somewhere (e.g., climate-change benefits from replacing diesel with biodiesel in Europe) do not come at the expense of increased impact elsewhere (e.g., climate change resulting from iLUC in South-East Asia). Regardless of the precision of the results, CLCA has already demonstrated its value: It has caused a review of policy for transport biofuels and provoked serious consideration of the life cycle consequences of biofuels, such as iLUC (Edwards et al. 2008).

Whereas sophisticated models are necessary to provide insights for policy development, the model results must be presented and interpreted clearly in order to inform decision makers. However, whereas the scientific results must be accurate (in the sense defined above), they need not be precise to provide policy support. We agree with Plevin and colleagues (2014) that ALCA is not a suitable basis for policy development because it cannot reliably meet the accuracy requirement.

However, though we agree that ALCA is not an appropriate basis for *development* of policy, we propose that it may be applicable in the *implementation* of policy. We suggest that CLCA, implemented with approaches such as CGE, should guide "big decisions," such as "should Europe promote biofuels?", but ALCA with simple allocation (see the Supporting Information on the Web) may be appropriate when designing the mechanics of policies to implement those decisions (including product labeling). For example, this pragmatic approach has been adopted in the European Union (EU)'s Renewable Energy Directive (EU 2009). This way, an economic operator will not have to engage in scenario making regarding, for example, how coproducts from a proposed biofuels plant will be used in 5 years' time.

LCA methods need to be updated to include the latest scientific understanding (e.g., on impacts of short-lived climate forcers, albedo, and effect of timing of greenhouse gas emissions and removals). These elements should be addressed in standards and product category rules and reflected in all forms of LCA studies.

Recognizing that LCA contains unavoidable uncertainties, the next step should be to deploy the approach known as "post-normal science," in which the results are improved and validated by discussion with an "extended peer community" (de Marchi and Ravetz 1999; Mitchell et al. 2004). LCA would then provide a conduit for public deliberation (such as suggested, e.g., by Sinclair et al. [2007]). In this role, LCA has a great deal to offer.

Notes

1. The distinction between the two approaches is set out in table S1 in the supporting information available on the Journal's website.
2. Price considerations are excluded from the biophysical form of CLCA; in effect, it is assumed that supply and demand are inelastic.

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Supporting Information

Supporting Information S1: This supporting information contains a table summarizing the main differences between attributional and consequential LCA.

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