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System Expansion and Substitution in LCA: A Lost Opportunity of ISO 14044 Amendment 2

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Fourteen years after their publication, the ISO standards for life cycle assessment (LCA) ISO 14040 (2006) and ISO 14044 (2006) have been revised. Most revisions were minor yet useful, but we are concerned by the manner in which amendment 2 to ISO 14044 (2020) added information on the system expansion procedure.

The LCA community has been eagerly looking forward to the clarification that an amendment to ISO 14044 (2006) would bring about to a largely confusing hierarchy to address the multi-functionality issue. We regret that amendment 2 (ISO 14044, 2020) has not removed this confusion.

The multi-functionality problem is the result of the fact that LCA isolates a product system from an economic production system, wherein multiple products/functions may be brought forward by single processes or systems. For instance, in an LCA of gasoline cars, the impact of the refinery is not only for producing gasoline, but also for producing other refinery products, such as diesel and kerosene. The issue at stake is now how to deal with those additional products. This note does not discuss the full multi-functionality problem (for which the reader is referred to the standard textbooks on LCA), but only addresses the issue of system expansion.

Let us have a close reading of the text of the original ISO 14044 (2006): "Wherever possible, allocation should be avoided by... expanding the product system to include the additional functions related to the co-products..."

The amendment (ISO 14044, 2020) adds an Annex which starts by reiterating these statements. In particular system expansion is described as follows: "expanding the product system to include additional functions related to the co-products … can be a means of avoiding allocation." Hereafter, however, the following is added: "the product system that is substituted by the co-product is integrated in the product system under study. In practice, the co-products are compared to other substitutable products, and the environmental burdens associated with the substituted product(s) are subtracted from the product system under study."

In the above text, there are two different interpretations of the term "system expansion" at play:

TABLE 1 | Overview of the main differences between the four proposed methods for dealing with multifunctional unit processes.

Solution of multifunctionality problem		Functional unit	System boundary
Avoiding substitution/allocation	Subdivision	Remains consistent with the goal and scope	Remains consistent with the goal and scope
	System expansion	Extra function(s) added	Includes co-product(s)
Performing substitution/allocation	Substitution	Remains consistent with the goal and scope	Extra process data added
	Allocation	Remains consistent with the goal and scope	Remains consistent with the goal and scope

1. Actual system expansion in which all function(s), corresponding to the multiple products involved in the multifunctionality issue, are maintained and thereby the functional unit is not isolated but expanded. This allows for functions from multiple products/co-products to be present in the functional unit.
2. Substitution, in which solving multi-functionality by reducing multi-product systems into single-product systems does take place, through subtraction of avoided burdens related to the co-products that are not part of the functional unit.

These two interpretations of the term "system expansion" each present a different solution to the multi-functionality issue. The first interpretation appears to have widespread traction [see McAuliffe et al. (2020) for an overview focussed on food] and the second is supported by the defunct standard ISO 14041 (1998). The amendment (ISO 14044, 2020) effectively rules out the first interpretation altogether: from now on the ISO standard prescribes that expanding the system to include additional functions must be understood as subtracting avoided burdens with the substitution method. The remainder of this article is devoted to highlighting and resolving this issue. It is not the purpose of our opinion paper to argue for either interpretation; the purpose of this paper is to distinguish both procedures and to underscore the value of both.

We first analyze how the different interpretations of the term "system expansion" may have come to be. ISO 14044 (I2006) described system expansion as a way to avoid allocation, but did not mention terms like "substitution" and "subtraction" which, coupled with the fact that the clarification in ISO 14041 (1998) was not carried over to ISO 14044 (2006), had the result that the term "system expansion" could legitimately be interpreted as including additional functions without substitution. Yet, because (ISO 14041, 1998) and subsequently (Tillman et al., 1994; ISO 13065, 2015), had suggested that including additional functions was equivalent to subtracting these functions, many LCA practitioners interpreted system expansion and substitution as synonymous [to prove our point, we refer to a methodological paper (Weidema, 2000), a case study (Nguyen and Hermansen, 2012), and an ISO-inspired standard (PAS 2050:2011, 2011)].

An amendment of the text on multifunctionality was indeed highly needed to clarify the distinction between system expansion proper and substitution. However, the present amendment effectively rules out the use of system expansion in the sense of expanding the functional unit to cover all functions provided by the multiple-product system. It only attaches the name "system expansion" to a procedure that is better described as "substitution."

Expanding the product system to include additional functions related to the co-products can be a means of avoiding allocation. System expansion results in a system that produces the function(s) expressed by the functional unit, as well as the additional function(s) that is (or are) provided by the unallocated co-product(s). System expansion does not require the collection of additional data, but the LCA as a whole clearly remains a data-intensive analysis.

By contrast, the substitution method applies a modeling step to maintain and isolate a single function, namely through a subtraction procedure. The substitution method requires the collection of additional and context-specific data, namely on the burdens of the substituted product(s) that is or are to be subtracted, on top of the already laborious data collection that an LCA involves by definition.

Both methods have value. We, therefore, in line with (ILCD handbook, 2010), argue for the inclusion of system expansion and substitution as separate options in the ISO standard 14044 (ISO 14044, 2006). System expansion is valuable because it does not require additional data or significant choices (see **Table 1**). Substitution is valuable because it allows to focus on individual products rather than multi-product systems (see **Table 1**). If ISO makes clear that adding functions differs from substitution, it would ensure that the standard is as complete/comprehensive as possible, i.e., also allowing for functional units that contain functions from multiple products, thus enlarging the scope of applications of LCA. In this way ISO 14044 continues to serve as a backbone for ILCD handbook (2010), PAS 2050:2011 (2011) and UNEP (2011), and numerous case studies, like (Nguyen and Hermansen, 2012).

Altogether, we envisage that a future revision of ISO 14044 will mention four distinct principles:

- avoiding substitution/allocation by subdividing the unit process;
- avoiding substitution/allocation by expanding the system to include the additional function(s);
- substitution of the additional function(s) by another product/other products;
- allocation of the multifunctional unit process by partitioning its flows over the products.

We have deliberately omitted to describe this as a hierarchy. If desired, a preference order may be added. See **Table 1** for a neutral overview of some characteristics.

As Weidema observed in his 2014 blog (Weidema, 2014): "the current ISO 14040/44 sometimes fail us in its role as a standard, that is, to minimize or eliminate unnecessary variation." The 2020 amendment (ISO 14044, 2020) has indeed eliminated a variation, namely system expansion proper, which we argue to be a useful variation, but also an official one, first priority in ISO's hierarchy (ISO 14044, 2006; McAuliffe et al., 2020). The amendment has relabeled another method (substitution) that was not explicitly mentioned in ISO 14044 (2006). While the inclusion of substitution is valuable, we consider the omission of system expansion a lost opportunity in the standardization and harmonization of LCA practice.

AUTHOR CONTRIBUTIONS

RH drafted and edited the text. KA, EB, MB, JG, SS, TS, and AZ suggested additions and improvements. All authors contributed to the article and approved the submitted version.

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