frontiers | Frontiers in Sustainability

TYPE Perspective
PUBLISHED 24 January 2024
DOI 10.3389/frsus.2024.1342223

OPEN ACCESS

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RECEIVED 21 November 2023
ACCEPTED 08 January 2024
PUBLISHED 24 January 2024

CITATION
André H (2024) "If less is more, how you keeping score?" Outlines of a life cycle assessment method to assess sufficiency. *Front. Sustain.* 5:1342223. doi: 10.3389/frsus.2024.1342223

"If less is more, how you keeping score?" Outlines of a life cycle assessment method to assess sufficiency

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It is increasingly clear that reaching environmental sustainability requires not only efficiency (reduced environmental impact per functionality) but also sufficiency measures (reduced environmental impact through reduced or changed functionality). Life cycle assessment (LCA) is a widely used tool to study environmental impacts related to consumption. However, because of the LCA convention of only comparing alternative products with equal functionality, it is currently inept as a method for assessing the environmental impacts of sufficiency measures. Against this background, this short paper aims to stimulate a discussion on how sufficiency measures can be assessed with LCA methodology. By analyzing the very few LCAs of explicit sufficiency measures in terms of the components of a functional unit (*what* function is provided, *how much*, for *how long*, and *how well*) features of a potential new branch of LCA methodology are outlined, called Sufficiency LCA. In Sufficiency LCA, product alternatives need to be similar enough so that the *what* component of the functional unit can be equal, while the other components, *how much*, *how long*, and *how well*, are allowed to be non-equal. Thus, a key feature of Sufficiency LCA concerns functional non-equivalence of compared product alternatives, which is not allowed or neglected in conventional LCA, but which could be allowed, acknowledged and quantified in Sufficiency LCA. Developing Sufficiency LCA could be critical considering that sufficiency measures are expected to be required, and that LCA is expected to be serviceable as decision-making support, in the transition toward environmental sustainability.

KEYWORDS

sufficiency, frugality, degrowth, minimalism, sustainable consumption, functional equivalence, functional unit, life cycle assessment

1 Introduction

> *"There's those thinking, more or less, less is more*
> *But if less is more, how you keeping score?"*
> (Hannan, 2007)

The evidence is mounting that reaching environmental sustainability in terms of, for instance, climate change requires measures not only based on efficiency but also sufficiency (Jackson, 2011; Wiedmann et al., 2020; Hickel et al., 2022; IPCC, 2022). Before discussing a more elaborate distinction, we can at this point describe *efficiency measures* as those that reduce environmental impact of consumption, or in life cycle assessment (LCA) terms, per

functional output.[1] S*ufficiency measures*, on the other hand, rather reduce environmental impact through reducing the level of consumption or the functional output.

LCA is expected to be a sustainability decision-making tool but is currently focused almost entirely on efficiency, which is a necessary but incomplete means to the end of sustainability (Pelletier et al., 2019). There are discussions in LCA contexts that can be argued to touch upon the concept of sufficiency implicitly (see Section 4). However, to my knowledge, there are only two LCAs that assess measures explicitly referred to as sufficiency measures (Brändström and Saidani, 2022; Wiprächtiger et al., 2022). There could be many explanations for this. One is that sufficiency measures are not yet widely implemented in society. Another explanation could be that sufficiency measures tend to be demand-side and user-oriented (Jungell-Michelsson and Heikkurinen, 2022), while LCA which tends to be supply-side and product-oriented. Moreover, given that a key characteristic of sufficiency measures is that they reduce the functional output, their assessment seems to require breaking a key convention of comparative LCA: that of only comparing alternatives with equal functional output. As a result, LCA seems to be currently inept as a methodology for assessing the environmental impacts of sufficiency measures. Due to their expected importance in sustainability transitions and, with that, increased implementation in society (Jackson, 2011; Wiedmann et al., 2020; Hickel et al., 2022) it is crucial that the LCA community finds ways of assessing them. Against this background, the purpose of this short paper is to stimulate a discussion on how sufficiency measures can be assessed within LCA. To do so, it is necessary to first understand what sufficiency measures are in general and how they may be interpreted in the context of LCA. Thereafter, the very few LCAs of explicit sufficiency measures are analyzed to propose outlines of a new LCA method, Sufficiency LCA.

2 What is a sufficiency measure?

Sufficiency means *doing without* or *getting by with less* (Alcott, 2008). It is a concept that can be linked to several strategies for sustainable development, such as circular economy (Potting et al., 2017) and degrowth (Kallis, 2011; Hickel et al., 2022), and social movements like voluntary simplicity, anti-consumption and downshifting (Jungell-Michelsson and Heikkurinen, 2022). The literature on sufficiency as a sustainability strategy has emerged, to large extent, as a critique to eco-modernism and its focus on efficiency measures, motivated by the proclivity of efficiency measures to cause rebound effects. Efficiency measures may for instance cause changed consumption behaviors that counteract the environmental benefits of potential efficiency gains. It should however be mentioned that sufficiency measures are by no means exempt from potential rebound effects (Alcott, 2008). Key to the concept of sufficiency is that doing without or getting by with less is argued to not necessarily imply less wellbeing or happiness, but often the contrary (Jungell-Michelsson and Heikkurinen, 2022).

From the above descriptions, the sufficiency concept can be understood as a strategy for sustainable development that aims to reduce environmental impacts of consumption through contributing to less, but sometimes, better consumption (c.f. less is more). There is, however, no clear understanding of what it means to operationalize sufficiency on a micro-level (Jungell-Michelsson and Heikkurinen, 2022), which is important in order to start a discussion on how to assess sufficiency in LCA. The International Panel on Climate Change defines sufficiency as *"a set of measures and daily practices that avoid demand for energy, materials, land and water while delivering human well-being for all within planetary boundaries"* (IPCC, 2022). Key parts of this definition are that sufficiency measures aim to decrease environmental impact by "avoid[ing] demand" for resources "while delivering human well-being". However, in order to operationalize sufficiency on a micro-level, a more specific definition is required. Fischer and Grießhammer (2013) propose that sufficiency on a micro-level can be defined as: *"modification of consumption patterns that help to respect the Earth's ecological boundaries while aspects of consumer benefit change."* In LCA terms, "aspects of consumer benefit" may be interpreted as the functional output of a product system delivered to a user (Rebitzer et al., 2004). To avoid that measures detrimental to human wellbeing are interpreted as sufficiency (i.e., "modification of consumption patterns" of food should not cause malnutrition or starvation) it could be added that sufficiency measures change aspects of consumer benefit "while delivering human well-being", inspired by the IPCC definition.

The definition by Fischer and Grießhammer (2013) encompasses that sufficiency can be *doing without*, *getting by with less* and, importantly, that it does not only refer to quantitative reductions, but also to *qualitative changes*, i.e., that less may be more, in the consumption of products and services. For example, sufficiency may refer to doing without a car and taking the bike, which could be a healthier means of transportation. It could also refer to accessing a car through car-sharing instead of private ownership. While this definition captures the diversity of the sufficiency concept, it also implies that sufficiency is, to large extent, an inherently subjective matter. Some changes in *consumer benefit*, i.e., functional output, may be objectively measurable while others will not. For instance, car sharing may, objectively, change the distance traveled per year and, subjectively, the convenience experienced by users. Further, because functional output, and whether it changes as a result of a measure, is at least partly a subjective matter, the definition by Fischer and Grießhammer (2013) implies there can be no, a priori, distinction between sufficiency and efficiency measures.[2] To illustrate, car sharing may be implemented in a very technical way (e.g., through a very smartly designed app) that allows users to enjoy the same benefits as with private ownership: at the same capacity to transport users and at the same level of convenience, in which case it would be an efficiency measure (since it does not considerably change the functional output). Car sharing could also be implemented in a non-technical way where users do experience a considerable decline in convenience, in which case it could be seen as a

1 Functional output refers to the performance of a product system (Rebitzer et al., 2004), in other words, the functions it delivers to a user.

2 This may also contribute to the lack of LCAs explicitly assessing sufficiency measures.

TABLE 1 Overview of how sufficiency measures, assessed in two previous LCAs (Brändström and Saidani, 2022; Wiprächtiger et al., 2022) and an ongoing research project on sufficiency measures at mountain stations, change functional output and environmental impact.

What	How much	How long	How well	Quantitative implications	
				Environmental impact	Change of functional output
Clothes to use (Wiprächtiger et al., 2022)	50% less	1 year - Unchanged	Not assessed	Reference flow: 50% less clothes	Easily quantifiable but not quantified
Mowed lawn (Brändström and Saidani, 2022)	Smaller lawn (−87.5%) Less frequent mowing (−50%)	16 years - Unchanged	Not assessed	Reference flow: - 87.5% less lawn - 93.75% less energy use	Easily quantifiable but not quantified
Nutritious, tasty and filling restaurant dinner at STF mountain station	For 1 person or X grams - Unchanged	1 evening - Unchanged	Change in guest satisfaction or each obligatory property	Inventory flow: Y% less helicopter transport	Less quantifiable

sufficiency measure (since the functional output does change considerably). Thus, instead of aiming to define what a sufficiency measure is in the context of LCA, it is perhaps more appropriate at this point to suggest the following distinction:

- efficiency measures are technical, product-oriented and imply relatively small changes in functional output
- sufficiency measures are user-oriented and imply considerable changes in functional output while (still) delivering human wellbeing

3 Suggestions for how to assess sufficiency within life cycle assessment

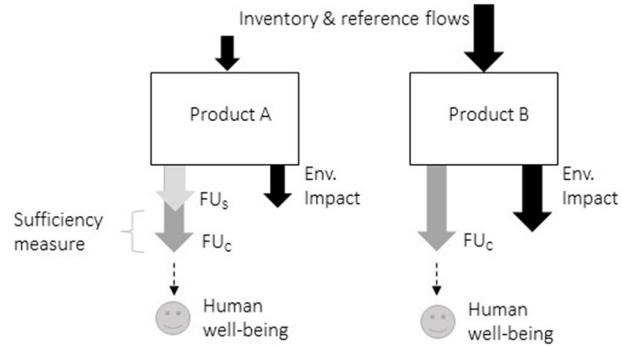
While it may not be possible to define, a priori, what a sufficiency measure in LCA is, it is nonetheless possible to outline a few components of a potential definition of "Sufficiency LCA". Since a characteristic feature of what may be referred to as sufficiency measures based on the suggested distinction is that they change the functional output of a product, it makes sense to use the components of a functional unit as a framework for this purpose: (a) what function is provided; (b) in what quantity (how much); (c) for what duration (how long) and (d) in what quality (how well) (European Commission, 2011).

Table 1 presents three examples of how sufficiency measures change the functional output in terms of the components of the functional unit and what this implies quantitatively for environmental impacts and the total change in functional output. The published examples concern the use of clothing (Wiprächtiger et al., 2022) and household lawns (Brändström and Saidani, 2022). The last example concerns a sufficiency measure that the Swedish Tourist Association (STF) considers implementing in their operation of mountain stations, offering accommodation and restaurant services in the Swedish backcountry: to reduce the amount of fresh ingredients used in the food served at their restaurants in order to reduce the need for helicopter transport.

In order for products to be comparable in LCA, *what* they deliver needs to be the same, at least in terms of the main function of the product. A distinction is made between *obligatory properties* and *positioning* properties (Weidema et al., 2004). It is on the basis of sharing a set of obligatory properties, included in the functional unit definition, that alternative products can be considered functionally equivalent and, hence, substitutable. Positioning properties are non-obligatory properties which nonetheless are relevant for the market position of a product, for instance, in terms of how products are evaluated or experienced by users (Weidema et al., 2004). These are typically less objectively quantifiable than obligatory properties. If there are relevant differences between product alternatives in terms of positioning properties it is recommended to make note of these qualitatively (Guinée, 1995). Sufficiency measures are likely to imply relevant changes in terms of a wide range of properties. This could warrant attempting to quantify properties that are more subjective than objective, and hence, less quantifiable.

Which properties to regard as obligatory and hence include in the *what* component of the functional unit definition depends on the market in which products are sold (Weidema et al., 2004). Products in a market are shaped by an interplay of producer and user requirements. Producers may decide what market segment to target and *what* their products should accordingly offer (Weidema et al., 2004). On the other hand, it is users who ultimately make consumption decisions based on what products they think are substitutable, which could suggest that the definition of obligatory properties could be based on user requirements and acceptability (Weidema et al., 2004; Salazar et al., 2015; Kjaer et al., 2016). In the case of restaurant dinners at mountain stations, the *what* component of the functional unit could be defined based on STF's ambition to, regardless of the amount of fresh ingredients, serve a dinner that is, among other things, nutritious, tasty and filling. Environmental properties may also be considered obligatory. However, since the purpose of LCA is to quantify environmental impacts, it is not meaningful to consider an environmental property as obligatory, unless it is possible to judge before doing the LCA whether a product has the property or not (Weidema et al., 2004).

The sufficiency measures assessed by Brändström and Saidani (2022) are reducing the size of the lawn and the frequency of lawn-mowing. These measures change the *how much* component of the functional unit of the sufficiency alternative (the smaller lawn), while the *what* component, essentially, having a mowed



- Functional unit reduced by the sufficiency measure, FU_s, for calculating environmental impact of Product A
- Functional unit for comparison with Product B, FU_c, of environmental impacts per functional unit
- Quantification of difference in functional output, i.e. "changed consumer benefits": $\Delta F = FU_c - FU_s$
- Product A and B both deliver human well-being

FIGURE 1
Components of a potential definition of "Sufficiency LCA". In black: inventory and reference flows and their resulting environmental impact; In gray: two measures of functional output, FU_S, functional unit, sufficiency; FU_C, functional unit, comparison.

lawn, is the same for both alternatives (i.e., the smaller and bigger lawn). In terms of quantitative implications of environmental impact, the combined effect of these sufficiency measures (87.5% reduction of lawn size and 50% less frequent mowing) is a 93.75% decrease in energy use for the smaller lawn compared to the bigger one (Brändström and Saidani, 2022). When sufficiency measures change the functional output of products in terms of the easily quantifiable *how much* or *how long* components (Brändström and Saidani, 2022; Wiprächtiger et al., 2022) quantifying the change in functional output is straightforward. The same cannot be said for sufficiency measures that change the *how well* component since this may often require quantification of subjective properties (Table 1).

In the case of restaurant dinners at STF mountain stations, it is the *how well* component that is expected to change as a result of the sufficiency measure. Serving food made from less fresh ingredients will most likely change the experiences of the guests considerably. This could be captured either through an aggregated measure, e.g., user satisfaction, or disaggregated in terms of each obligatory property. Some properties may be experienced as changing for the worse, e.g., taste, while others may be experienced as changing for the better, e.g., price and environmental performance. This implies that the identification of which properties to include in the functional unit is ever more important in the context of Sufficiency LCA. If "less is more" it is important to highlight how all relevant properties change as a result of a sufficiency measure. On the whole, a dinner composed of less fresh ingredients would most likely be experienced as inferior to the alternative, in other words, a reduced functional output in terms of the *how well* component. Similar to how the reduction of lawn size and mowing frequency could reduce the energy use associated with *a mowed lawn* by 93.75% (Brändström and Saidani, 2022), the decrease in fresh ingredients could reduce the energy use, and consequently, climate change impact of dinners at STF mountain stations to some degree.

Based on the analysis above, some components of a potential definition of Sufficiency LCA may be outlined (Figure 1). Product alternatives in Sufficiency LCA need to be similar enough so that the *what* component of the functional unit can be equal, while other components of the functional unit, *how much*, *how long* and *how well*, are allowed to be non-equal. An absolute limit to such functional non-equivalency is that sufficiency measures must not undermine basic human needs. What criteria could be suitable for ensuring this could be further discussed. One option could be that the functional output specified by FU_s (see Figure 1) must be acceptable to the concerned user group. In comparative LCA, acceptance to users has been a criteria to establish functional equivalence (Weidema et al., 2004). Thus, Sufficiency LCA would be open to the possibility that alternatives with similar but non-equal functional output could be accepted by users and thus regarded functionally equivalent. The non-equivalency reflects how sufficiency measures change, and in most cases probably reduce, the functional output of a product. Since sufficiency measures intend to reduce environmental impact *through* reducing the functional output, these changes are important to quantify in sufficiency LCA because they change the inventory and reference flows of the product (Product A in Figure 1). Therefore, this reduced functional output, represented by functional unit, FU_S (S denoting sufficiency) is used to quantify environmental impacts of Product A (Figure 1). However, when comparing the environmental impacts per functional unit, a reduced functional output would imply, ceteris paribus, an increased environmental impact per functional unit. Therefore, for comparing the alternative products, it is key to not use FU_S and instead use an equal functional unit, FU_C (C denoting comparison), representing the functional output of Product B as well as Product A without the sufficiency measure. In addition, since the change in functional output represents a key feature of sufficiency measures, it is in itself a relevant result. Therefore, in Sufficiency LCA, it could be sensible to present the change in

functional output as a separate result alongside results on changes in environmental impact.

4 Discussion

Motivated by the increasing relevance of sufficiency measures and the realization that comparative LCA is currently inept as a methodology for assessing their environmental implications, this paper outlines how sufficiency measures could be assessed with LCA methodology. Based on an analysis of a few examples of sufficiency measures, the following definition of "Sufficiency LCA" is suggested:

> *Sufficiency LCA is a type of LCA that compares and assumes functional equivalence of products with similar but non-equal functional output, where the functional output of a product used to calculate its environmental impact is differentiated from the functional output used to compare environmental impact of an alternative product. In addition, the difference between the functional outputs is quantified as a measurement of how a sufficiency measure changes consumer benefits and presented as a separate result alongside changes in environmental impact.*

Although LCAs of explicit sufficiency measures are rare, there are LCA contexts that can be argued to touch upon the concept of sufficiency implicitly, in which the idea of loosening the requirements on functional equivalence have been discussed previously. For instance, waste prevention strategies (i.e., reducing the amount of waste generated) reduce society's need for the function of waste treatment (Ekvall et al., 2007; Cleary, 2010). Therefore, to compare all strategies of the waste hierarchy, LCA practitioners need to make a "philosophical leap" in considering waste prevention as functionally equivalent to waste treatment (e.g., incineration or recycling) (Cleary, 2010). Further, it may be considered a sufficiency measure to get by with an older product instead of buying a new one with additional features and improved performance. Thus, to compare newer and older product generations, Kim et al. (2016) proposed that LCAs must allow that the functional output of newer products may be greater than older ones and that such comparisons are valid as long as the alternatives are acceptable to the considered users (c.f. "similar but non-equal functional output" from the definition above). To represent how functionality of alternatives may differ, they suggested using the following categorization of product properties (Kim et al., 2016):

- Basic, meaning those properties, that, if absent, causes user dissatisfaction and, conversely, need to be present for a product to be considered an alternative.
- Performance, meaning those properties that may provide greater user satisfaction.
- Excitement features, meaning those properties which, if absent, would not cause dissatisfaction.

Although not explicitly discussed in the context of sufficiency, this categorization could clearly be useful in further developments of Sufficiency LCA. For instance, fulfillment of basic properties could serve as a criteria for when alternatives with similar but non-equal functional output can be considered functionally equivalent. Further examples that have discussed loosening the requirements on functional equivalence are e.g., design for environment (Lagerstedt et al., 2003) and product service systems (Salazar et al., 2015; Kjaer et al., 2016). As discussed previously, the distinction between efficiency and sufficiency is not always clearcut and product service systems based on e.g., sharing may very well be categorized as a sufficiency measure according to the suggested distinction (Section 2). Given these examples of LCA contexts that implicitly touch on the concept of sufficiency and have called for loosening the requirements on functional equivalence, this particular element of Sufficiency LCA is not a novel idea. In light of this, Sufficiency LCA may be regarded as an umbrella term encompassing LCA approaches where methodological issues related to functional equivalence are particularly pronounced because of their aim to assess measures based on the strategy of reducing environmental impact through reducing or considerably changing functional output.

In addition, looking at the suggested definition above, it may be countered that the idea of functional equivalence is an ideal and that LCAs commonly assume functional equivalence of products with similar but non-equal functional output. With this in mind, it could be argued that Sufficiency LCA is not that different from conventional LCA after all. However, as shown by these previous discussions, there is indeed reluctance within the LCA community to accept comparisons between products with considerably non-equal functional output. Hopefully, this short paper can further the discussions regarding in what contexts comparisons of functionally non-equivalent alternatives are acceptable and valuable. The key difference between conventional and Sufficiency LCA is that conventional LCA neglects functional non-equivalence while Sufficiency LCA would acknowledge and attempt to quantify it. By doing so, Sufficiency LCA could contribute to more fair comparisons and provide insight into both the environmental performance of sufficiency measures and to potential barriers in terms of changed functional output that actors may need to address for acceptability and implementation. Considering the need for a more widespread implementation of sufficiency measures in society (Jackson, 2011; Wiedmann et al., 2020; Hickel et al., 2022; IPCC, 2022) Sufficiency LCA could be an important addition to the family of LCA methodologies.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

HA: Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Visualization, Writing–original draft, Writing–review & editing.

Funding

The author(s) declare financial support was received for the research, authorship, and/or publication of this article. The research was supported financially by BFUF, the research and development fund of the Swedish Tourism & Hospitality Industry (Grant Number: 2022-275).

Acknowledgments

I am grateful to Professor Anna Björklund and Professor Göran Finnveden for discussions on the topic of Sufficiency LCA and valuable comments on the manuscript. The collaboration with the Swedish Tourist Association (STF) is also greatly appreciated.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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