Reconsidering the assessment method of Environmental implications of Circular Economy in the Built Environment

S C Andersen¹, ²*, M Birkved²

¹Buildings & Environment, Danish Technological Institute, Gregersensvej, DK-2630 Taastrup, Denmark.
²SDU Life Cycle Engineering, Department of Green Technology (IGT), University of Southern Denmark, Campusvej 55, 5230, Odense-M, Denmark

*Email: saca@igt.sdu.dk

Abstract. Are we capable of addressing environmental consequences on societal scale of circular solutions for the Built Environment, or merely capable of addressing these impacts applying a narrow product/corporation perspective? Considering evaluations and quantifications of environmental implications associated with implementations of Circular Economy (CE) design processes in the Built Environment, we postulate that these solutions necessitate decision-support tool-advancement, as CE does not allow for business-as-usual (BAU) assessments only. The BAU assessments of environmental impacts in the built environment, seem to paint a certain picture of the circularity paradigm. The question, however, is whether, by relying on simplified assessments, we end up barely making it to the finish line, very late, and risking losing focus and creating sectoral burden-shifting. Application of LCA has created a paradoxical situation in the building industry. Gaining more experience in application of LCA, the industry steadily increases the complexity level of the questions to be addressed by LCA, thus increasing scale and complexity of systems to be assessed. Hence, currently, large systems such as CE models for the built environment, are often assessed in the same manner as we assess single buildings and building parts, despite that CE models have a much higher potential to generate feedback effects, so that the system under assessment, changes due to the entity/service being assessed. The main question is hence whether life cycle assessors operating within the built environment are aware of the challenges they are facing when answering questions regarding CE, and if these are addressed, assessment wise, in a /appropriate manner? Secondly, we need to consider how we facilitate assessment of systems at various physical and temporal scales in such a way that it becomes economically and technically feasible for the industry to address complex sustainability questions. This paper discusses possible future application potentials of LCA and propose consistent scenario definition, and thus looks into the question: how come, that we assess almost all systems in a ‘static’ manner, while being completely aware of that we live in a dynamic world? Are we, within LCA, addressing the need for improving the realism of the models that we derive in a sufficient and applicable manner?

Keywords: Built Environment Circular Economy, LCA as Decision Support, Prospective Scenario development, Shared Socioeconomic Pathways
1. Introduction

In recent years, circular economy (CE) has been introduced as a way to obtain environmental benefits for society, e.g., by reducing waste generation, Greenhouse Gas (GHG) emissions, resource consumptions etc. CE, as most people refer to it today, was introduced by the Ellen MacArthur Foundation in the early 10s (through e.g., their ‘Towards the Circular Economy’ series [1-3]). However, the concept was originally coined by Pearce & Turner (1990) [4], defining it a system or economy where technological feedback mechanism or natural ecosystem feedback mechanisms are applied to recycle waste into resources, thus ensuring a constant or increasing stock of resources over time [5].

Since, the definition of the CE paradigm has been discussed widely (e.g. [6, 7]), and along with these discussions also the considerations on how we assess and quantify the potential benefits of CE (e.g. [8-13]).

As observed by Kirchherr & van Santen (2019) [14], there is an immensely growing body of research considering CE in academia, however, this is often decoupled from practice. Considering the 5 observations made in Kirchherr & van Santen (2019) [14], all of them resonate. However, we think it’s interesting to observe that projects, putting together academia and practitioners to implement CE, are gaining tractions, e.g. through grand solutions projects like Circle Bank [15]. We also observe a confirmation on the lack of knowledge on what works on average.

CE covers many aspects, and should be seen, merely, as a framework of thought or a means to an end goal, but then the question on method of calculation appears. While the choice of proper tool and method, depends on the question asked, work onto standardizing the terms and measurement indicators of CE, was commenced in 2018, through the ISO TC 323. While the work covers standardization within implementation framework, business models and value chains, measuring framework etc [16], also the relationship between LCA and CE is debated.

While many of the observations above, concern the general discussion on CE, discussions and development with a more narrow focus on the construction industry have also been taking place, both with a focus on how to implement and apply CE, but also more specifically, in how to measure or calculate the benefits [17-21].

A tendency is observed, that CE is praised for being the solution to the climate change mitigation [22, 23], and LCA can be used to provide the sole argument. However, while we do not dispute the potential, by this contribution, we want to question the method for calculating this potential, by postulating that the current LCA application practice, does not answer correctly to the questions asked when addressing CE – and if it does, the right question is not necessarily posed.

2. Background

Life Cycle Assessment (LCA) has, over many years, proved its value as decision support, by being a method of quantifying potential environmental impacts [24]. When talking LCA, two main modelling approaches are mainly defined: Attributional and Consequential LCA (ALCA and CLCA respectively). Over time, many descriptions of their differences, along with applications, assumptions and methodological choices have been published (e.g. [25]).

However, regardless of the modelling approach chosen, and the existence of a general methodology framework [26, 27], many assumptions and methodological choices are applied when performing an LCA, and these have an impact on the final impact assessment results.

A general distinctness of the two modelling approaches is, whereas attributional LCA is focused on describing and estimating a determined share of global environmental impact of a given product or service, the consequential approach estimates the environmental impacts affected and caused by the products or service. In other words: ALCA describes the potential environmental impacts, by assessing relevant flows within a/the chosen system, e.g., manufacturing a certain product, whereas CLCA describes the environmental impact potential changes, by assessing how relevant flows change as a response to a decision, e.g., to manufacture a certain product. By this, it can also be said, that the approaches answer to distinctively different question. ALCA can be said to ask: How big a share of the
environmental impacts in/of the world, can be allocated to a given product or service? Whereas CLCA asks: What environmental consequences does a given product or service entail?

Considering the questions asked and the decisions support made on design solutions in the Built Environment, by using Life Cycle Assessment (LCA), the environmental impacts are, to a great extent, assessed by using LCA standards related to the Built Environment; EN15804 [28] and EN15978 [29]. While these standards have helped paving the way for LCA on a broad scale industrial scale (which can be seen in recent legislative development, e.g. the Danish regulations [30]), there may be a misalignment to the central considerations needed, when introducing the CE paradigm.

Depending on the modelling approach chosen by the LCA practitioner, assumptions and methodological choices vary, as the assessed system differs. However, the main objective of the application of LCA has been, and is, to avoid burden shifting and provide comparatively valid decision support.

While, in the linear economy (LE), considering take-make-use-waste, the main focus has been on avoiding burden shifting across the life cycle stages and/or impact categories, the CE introduces an inevitable additional dimension, namely the risk of burden shifting across product system boundaries, including extended spatial and temporal resolutions. While this dimension is of course also at risk in a linear economy, CE is based on principles of circling a product into loops, through either open- or closed-loop recycling. This, inevitably, should lead to practitioners rethinking and refining the questions asked for LCA to answer.

2.1. Literature derived recommendations and concerns for assessment of CE

A position paper published in 2020 [31] highlights some of the potential issues and pitfalls, when aiming to adopt and apply LCA to answer the CE questions. One of the mentioned challenges is “The inclusion of all relevant resources and impacts, i.e. a full economy-wide Life Cycle Sustainability Assessment perspective” [31], which we find especially important, considering transition from LE to CE decision support.

While the position paper does not make explicit recommendation on what LCA correct methodology to apply, it underlines the need to apply LCA as a methodology for establishing more robust CE strategies, when also considering potential consequences upstream and downstream from the CE strategy applied. Additionally, the authors of the position paper [31] call for the awareness and need of involving the LCA community, when addressing the implementation of LCA in the CE decision-making framework.

Peña et al (2020) [31] pinpoint, that there may be an issue in the way the industry (defined broadly) is trying to answer questions regarding CE, using the LE, and the historically applied LCA models, as a frame of reference. This is also repeated by Weidema (2020) [5], where he suggested: “For both LCA and CE, it may be more economical to circle back to the original intentions and definitions, than to spiral down blind alleys of simplified interpretations and applications.”[5].

2.2. LCA for assessment of CE seen up front

The methodological LCA approach applied in the construction industry, historically, must be defined as pivoting around the attributional approach (as impacts are allocated accordingly to the product assessed, being that a material or building). This tendency is also found when reviewing readily available studies applying LCA for as CE, where the main body has been found to apply attributional LCA. Other studies are performing a mix of or none-specifically-defined methods or approaches, and few apply the consequential LCA methodology. Most of the reviewed studies conclude that CE ‘pays off’ however, the questions asked are rarely provided/elaborated on or are asked in very broad terms.

Introductions of CLCA in the construction industry, is mentioned throughout the literature in e.g., [32, 33]. While the studies embrace the implementation and application of consequential LCA in the building sector, it is based on different aspects and cases. Buyle et al (2018) [33] present a case study of a Belgian dwelling, assessing the environmental performance using both an attributional and consequential approach, respectively. They conclude, that the results demonstrate a clear difference in
the environmental profiles, however, the questions asked with respectively ALCA and CLCA are different. [33]. However, the interesting aspect in such a ‘comparative’ study, would be the direction in which the models and results points, and what questions can be answered.

Buyle et al (2019) [32] assesses a case study of an internal wall design, applying CLCA and life cycle costing (LCC). In the LCA modelling, they introduce different scenario modelling approaches, considering how to determine the marginal suppliers, amongst other differing in whether assumptions are based on retrospective or prospective data. Additionally, they introduce scenarios with different EoL potential [32]. The results found, represents a large range of potential impact outcomes, and could thus be highlighted in the conclusion of the importance of presenting multiple potential scenarios, from which unexpected consequences could be determined for a range of designs or strategies [32].

2.3. Application of LCA for prospective assessments within the built environment

Examples of studies trying to evaluate the application of LCA within the Built Environmental, in the context of CE, are adapting the method to include/consider multiple cycles and allocation methods, e.g. [34-36], dynamic aspects considering e.g. forecasting principles in scenario development, e.g. [37-39], and specific prospective scenario developments, e.g. [40, 41].

2.4. Real-world representation vs. practical issues for applying LCA

By this paper, we wish to extend the discussion on how LCA should not be used as a definite and final answer, but rather as a very useful technique to quantify potential impacts on the environment, caused by different CE strategies and their prospected pathways.

While research, and to some extent the LCA community as such, dares to ask some of these questions, there seems to be a misalignment to the industry. This misalignment may to some extend be caused by the fact that the building industry has been introduced to LCA through standardized methods, pivoting around ALCA. The acceptance, and currently rapid implementation of LCA, is thus based on the attributional approach. Thus, if the design and method of ALCA has made the concept of LCA comprehensible to a broader field, we should not disregard these assets entirely.

However, a danger appears when the applicable understanding of LCA in the industry is suddenly the basis of developing ‘new (hybrid) methods’ or answering ‘new questions’ for which ALCA can not necessarily be deemed suitable.

3. Suggested approach

As presented in the previous section, the existence and use of LCA has existed for many years and has been discussed widely. Against the transition into a CE, the discussion has further developed, as there appears to be partially motivation for altering the applied LCA method (as is evident from the European norms), to fit into the new paradigm.

We suggest however, as also suggested by e.g. Weidema (2020) [5], that we take a step back as a community, acknowledging that the construction industry did not “invent” the LCA methodologies, and explore the suitability of the available approaches for answering the questions raised by the CE agenda, while keeping in the original intentions and possible available LCA approaches.

The single components of the approach suggested in this paper are not new, as they are based on several initiatives already taking place and the individual methods used in this paper are well known and applied in their respective established lines of research. However, the aggregated framework for assessments has not, to the best of our knowledge, been proposed and tested extensively. The coupling of them, is only found in isolated parts of the literature, and mostly only as partial couplings.

While, to some extent, accepting the application of the BAU LCAs, following the framework of EN15804 and EN15978, we suggest supplementing the knowledge gap of societal consequences, caused by CE strategies, by applying CLCA.

An assessment framework is proposed, based on the most recent development within climate modelling, the Shared Socioeconomic Pathways (SSPs) framework, extended with dynamic Material
Flow Analysis (MFA) and dynamic consequential Life Cycle Assessment (cLCA). See the conceptual schematic in Figure 1.

Whereas the LCA approach and the questions asked, which is the main focus and critique point in this paper, it is proposed to apply the consequential approach, the value of it would inherently not appear, if not coupled with qualifying prospective scenario forecasting.

While the consequential approach allows for addressing cross-sectional and societal challenges and changes, the introduction of using consensus-based climate modelling framework, allows for the variety of future pathways to be modelled, consequentially resulting in differing materials stocks, and coherent potential changes in society.

![Image](image_url)

**Figure 1.** Conceptual schematic of the proposed assessment framework

Whereas the environmental cost of a specific building design and material could and should (as this is slowly gaining traction and may be the comprehensible for the broader industry to accept LCA), still be determined through simple accounting like LCA, we suggest reconsidering the method which we apply to model our future scenarios e.g., EoL, R-strategies applied, design strategies – all of which necessitates forecasting of future designs or/and policy decision making.

Even though, to date, there is a lack of consequential LCAs in the construction industry, we postulate that this supplementary approach is absolutely necessary, in order to take into account potential rebound effects, of proposed CE strategies, policies and design solutions in the building industry.

4. **Discussion**

Acknowledging that the discussion on LCA approaches and suitability, dives into a general discussion, which has been going on in the LCA community for many years, we’re focusing this paper’s discussion on the construction industry. Considering the rapid implementation at current stage, with an industry gaining more experience in the application of LCA, we find it important to question the approach(es) generally applied, concurrently with the increase of the complexity level of the questions which are expected to be addressed using LCA.

We find that an interesting shift appears, in the transition from using LCA merely as accounting tool for impact accounting, to using it as a part of (prospective) decision support in relation to future processes. In this distinction also lies an inherent issue in the nature of ‘what is known’ (a retrospective question) and ‘what is unknown’ (a prospective question).

In the accounting of what has (retrospectively) happened, or with the desire to pinpoint the hot-spots in a specific products system boundary, the attributional approach may be suitable. Additionally, the clearly defined modules in the standards EN15804 and EN15978 [28, 29], have made application more accessible for non-LCA experts, as it simplifies modelling to a wide extent. However, by introducing module D, impacts beyond the system boundary, the standards open up for taking into account reuse, recovery, and recycling potential. Modul D is now being exploited more than ever, considering the transition into CE.
Thus, in nature, module D may be argued to actually consider potential impacts (being that positive or negative), in a different logic, adhering to the consequential approach. Thus, historically, some limitations of the included approach have already been questioned, or fitted, due to a lack of suitability to the questions asked or encountered in practice.

As module D is to be reported separately from other life cycle phases, most LCA assessors acknowledge that this module has a different nature, however, against the background of assessing CE strategies, assessors start asking questions about how the future should be modelled (scenarios modelling), which in fact will also influence the modules B (use phase) and C (end of life) as well.

When developing scenarios (which everything following module A1-A5, as defined by the European norm, must inherently be defined as), these have historically been based on BAU, statistics, and historical data, thus retrospectively. While this may have been sufficient, in the process of introducing the LCA methodology and thus depicting the models as static, the growing interest in answering new questions using LCA, presents a need for reconsidering which basis we project onto the scenarios applied in the industry, considering e.g., higher potential to generate feedback effects, so that the system under assessment, changes due to the entity/service being assessed, or rebound effects.

When discussing future scenarios in the context of CE, many practitioners wish to accommodate the potential of e.g., reuse. However, the applied modelling approach through e.g., EN15804, does not naturally allow for answering these questions, as the systems are modelled based on the assumptions that impacts should be allocated to the assessed product.

4.1. Further research

While the approach suggested in this paper, is still in its infancy, it is based upon a large body of growing work. However, as argued, in order for the industry to pursue a CE agenda proactively, there is a need for extending the pool of evidence, on which decision making can be based. Once, such a pool of evidence is established, the discussion regarding methodology approach, questions asked, and policy support can be qualified.

While the suggested approach is not relevant for a case-by-case hot-spot analysis, the authors see a need in quantifying various development scenarios, enabling policymakers etc. to base decisions upon a pool of evidence, enabling to draw averaged conclusions. More specifically, there is a need for assessing CE design implementations at various design scales, considering the consequences at societal level, instead of just the single product design.

5. Conclusion

While the hypothesis of this paper is not an entirely new question in the LCA community, we aim to (re)open the discussion relating the questions asked, future scenarios designed and LCA approach applied, within the Built Environment. Considering the transitions into CE, the BAU LCA modelling in the Built Environment should be reconsidered. Not necessarily replaced, as we have to acknowledge the great span of knowledge and understanding on LCA in the industry, however we suggest we start supplementing the approach to develop decisions making knowledge.

Considering the nature of uncertainty in the future, which should however be of great focus when talking CE strategies, we suggest supplementing the BAU LCA, based on the attributional approach, with assessments according to the consequential approach. This supplemental approach could help enlighten the industry and policy makers on environmental impact of societal consequences and takes into account rebound effects when implementing potential strategies and solutions through CE.

In the modelling of future scenarios, it should also be embraced that we cannot determine the outcomes as one definite. Future scenarios should be modelled considering the span of possible outcome, and hence preferably based on ex-ante models, and prospective consensus multi-scenario assessment framework.
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