Prospective, Anticipatory and Ex-Ante – What's the Difference? Sorting Out Concepts for Time-Related LCA

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1. Introduction

Most life cycle assessment (LCA) studies conducted historically have considered technologies approximately as they are at the time of the study, often in a mature state of development [1]. However, an increasing number of LCA studies attempt to assess emerging technologies in imagined states at future points in time. The goal of such LCAs is typically to foresee potential impacts of a technology long before it has reached large-scale production and commerzialization. Such studies can be used to improve technologies and inform strategic technology choices. LCAs with such goals are often referred to using terms such as prospective, anticipatory or ex-ante. However, a clear distinction between these types of future-oriented LCAs is lacking in the literature [2]. With this contribution, we aim to sort these concepts into a typology of time-related LCAs, contributing to clearer communication and more purposeful methodological choices.

2. Materials and Methods

Existing definitions and frameworks for prospective, anticipatory and ex-ante LCA were reviewed and analyzed. A series of workshops were held within the author group, where the types of LCA were discussed regading their qualitatively important differences, with a focus on time-related aspects. A final typology consisting of three dimensions was found to capture the most important differences of the various time-related LCA types in a relevant manner. The typology was then applied to describe and discuss the range of time-related LCA types identified in the literature: prospective, retrospective, ex-ante, ex-post, lab-scale, anticipatory, attributional, consequential and dynamic LCA.

3. Results and Discussion

3.1. Real time

The first dimension is real time (measured in years). This dimension captures the time difference between the functional unit (an operationalization of the modelled technology) and the LCA. If the technology is modelled at approximately the same time as when the LCA is conducted, it can be called *contemporary* LCA. If the technology is modelled at a future point in time relative to the analysis, it can be called *prospective* LCA, and *retrospective* LCA if it is modelled at a past point in time relative to the study. This time dimension in LCA was similarly outlined by Sandén and Karlström [3]. In addition, *dynamic* LCA accounts for that a technology can be "stretched out" along the real time dimension, so that parts of the system exist at a past time, some parts exist at the present time, and other parts exist at a future time.

3.2. Maturity

The second dimension is technology maturity. A technology can be mature or immature at a certain point in the real time, which can be measured by ordinal scales for technology readiness levels (TRLs) or manufacturing readiness levels (MRLs). Several types of LCA explicitly aim at assessing either mature or immature technologies. *Ex-ante* LCA considers technologies that are immature at the time of the study but model them in a future when they are assumed to have become mature [4]. Ex-ante LCA is thus a specific type of prospective LCA for which the maturity is low at the time of the study but assumed high at the future time of the functional unit. In contrast, *ex-post* LCA refers to studies of technologies that have reached maturity at the time of the study, i.e. the historically most common type of LCA performed. *Anticipatory* LCA is effectively similar to ex-ante LCA by also modelling technologies that are immature at the time of the study at a future mature state. However, in addition to that, anticipatory LCA also includes an aspect unrelated to time, namely the inclusion of numerous stakeholders in shaping the LCA study [5]. A final type of LCA related to maturity is *lab-scale* LCA, which is a contemporary LCA of an immature technology with the aim of suggesting improvements to technology developers. The idea of having real time and maturity as two orthogonal dimensions has previously been proposed by Thonemann et al. [1]. Figure 1 provides a

schematic illustration of the two dimensions real time and maturity, with several time-related LCA types shown.

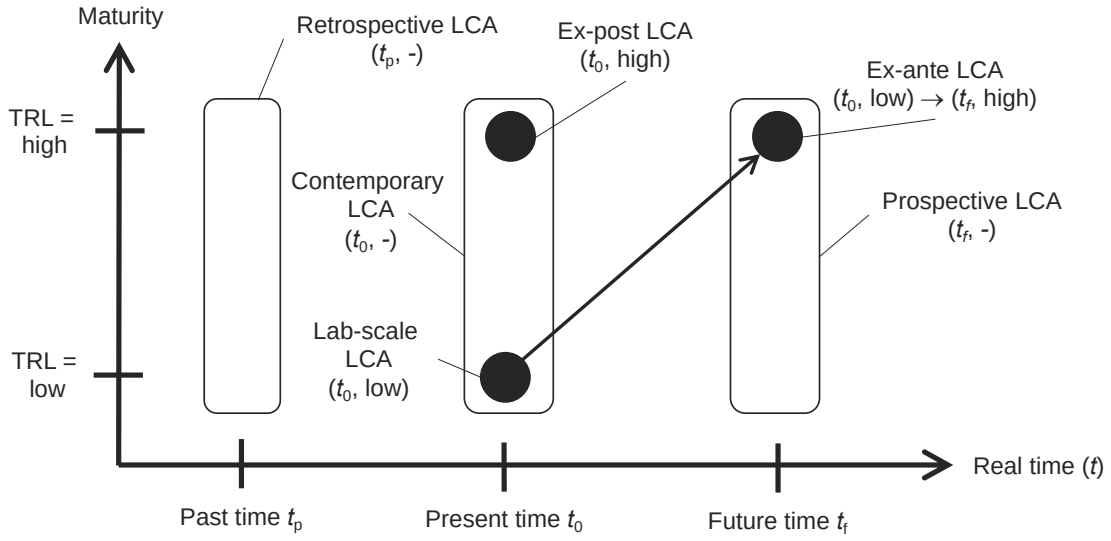

Figure 1: Schematic illustration of the dimensions real time and maturity with several time-related LCA types shown.

3.3. Causality

The third dimension is causality. Some LCA studies mainly consider causes of a functional unit, which is often referred to as *attributional* LCA. Other LCA studies mainly consider effects of a functional unit, which can be called *consequential* LCA. While the former can be said to look backwards in time, the latter can be said to look forward in time from the perspective of the functional unit. Both types can, however, be retrospective, contemporary, or prospective LCAs as defined above. It is also possible to consider different types of causality, which relate differently to real time and technology maturity. Causality through physical flows of energy and matter along a life cycle is typically considered in LCA; in fact, tracking these flows is often what forms the basis of the life cycle and its impacts. Physical causal chains are often modelled as if they had no extension in real time but located roughly to the point in time of the functional unit. This is especially striking for input-output LCA, which assumes that infinitely long causal chains are collapsed into one year. Some studies, in particular consequential LCAs, also consider causality in terms of marginal market effects. In addition, albeit seldom included in LCA studies, other possible types of causality include rebound effects as well as efficiency improvements from learning and economies of scale, where the latter has been shown to be particularly relevant for immature technologies [3].

4. Conclusions

In this contribution, three dimensions of LCA studies have been outlined: real time, technology maturity and causality. Based on these dimensions, it is possible to describe prospective, retrospective, ex-ante, ex-post, lab-scale, anticipatory, attributional, consequential and dynamic LCA regarding their temporal aspects. Hopefully, these dimensions can help clarify the time-related differences and similarities between these LCA types, which in turn can help LCA practitioners to choose LCA types that fit the goals of their studies.

5. References

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