THESIS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

How does LCA work in sustainable building practices?
The case for a pragmatic philosophy of life cycle assessment

SJOUKE BEEMSTERBOER

Department of Architecture and Civil Engineering

CHALMERS UNIVERSITY OF TECHNOLOGY

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Department of Architecture and Civil Engineering
Chalmers University of Technology
SE-412 96 Gothenburg
Sweden
Telephone + 46 (0)31-772 1000

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SJOUKE BEEMSTERBOER
Department of Architecture and Civil Engineering
Division of Building Technology, Sustainable Building
Chalmers University of Technology

Abstract

In recent years, environmental life cycle assessment (LCA) has become a rapidly growing practice among Swedish building companies, accompanied by a corresponding increase in scientific literature. Mostly, building LCA research has focussed on developing assessment tools and providing credible environmental information to support informed decision-making. In doing so, little empirical attention has been given to how LCA is actually used in building projects and organisations, and to how practitioners handle the recurring tension between scientific credibility and practical utility in LCA.

To address these issues, this dissertation has examined LCA-based practices in the context of Swedish building companies between 2017 and 2025. Studies have been carried out to examine simplification practices in the LCA literature (Paper I), the substantive effectiveness of LCA use in a development project for a standardised building design (Paper II), and the evolution of LCA-based practices in building companies responding to legislation on building climate declarations (Paper III). The findings of these studies demonstrate the intricate relations between scientific and contextually adaptive inclinations in LCA. The studies provided evidence of legitimate LCA-based practices that adjust what is assumed to be a relatively standardised LCA methodology to different purposes and contextual settings.

The findings support the case for a pragmatic philosophy of LCA use. Prioritising the practical usefulness and effects of LCA constitutes a response to deeply held beliefs in the intrinsic value of scientifically credible LCA knowledge. A pragmatic philosophy explains why LCA practices vary, as they are aligned with different purposes and contextual settings. Rather than being expressions of subjectivity or inaptitude, a pragmatic philosophy supports the notion that adjustments in LCA-based practices can be valid responses to real opportunities, constraints, and ambitions in the application context. The dissertation concludes that a pragmatic approach may support LCA researchers and practitioners in becoming more responsive to practical conditions for understanding and addressing product environmental impacts in building and other settings.

Keywords: Life cycle assessment, LCA, building, pragmatism, practice, practical utility, credibility

How does LCA work in sustainable building practices?
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SJOUKE BEEMSTERBOER
Institutionen för Arkitektur och samhällsbyggnadsteknik
Avdelningen för Byggnadsteknologi, Hållbart byggande
Chalmers tekniska högskola

Sammanfattning

Under de senaste åren har livscykelanalys (LCA) blivit en snabbt växande praktik bland svenska byggföretag. Forskning om byggnadsrelaterad LCA har främst fokuserat på att utveckla bedömningsverktyg och ta fram trovärdig miljöinformation för att stödja beslutsfattande. Dock har begränsad uppmärksamhet ägnats åt empiriska studier kring hur LCA faktiskt används i byggprojekt och organisationer, samt hur LCA-analytiker och -användare hanterar den återkommande spänningen mellan trovärdighet och praktisk användbarhet i LCA.

För att ta itu med dessa frågor har denna avhandling undersökt LCA-baserad praktik i kontexten av svenska byggföretag mellan 2017 och 2025. Studier har genomförts för att undersöka förenklingsmetoder i LCA-litteraturen (Artikel I), effektiviteten av LCA-användning i ett utvecklingsprojekt för en standardiserad byggnadsdesign (Artikel II), samt utvecklingen av LCA-baserad praktik i byggföretag i samband med lagstiftningen om klimatdeklarationer för byggnader (Artikel III). Resultaten från dessa studier visar på ett intrikat samspel mellan vetenskapliga och kontextuellt anpassade inriktningar inom LCA. Studierna visade att LCA-baserad praktik anpassas från en relativt standardiserad LCA-metodik till olika syften och kontextuella förhållanden.

Resultaten stödjer användandet av en pragmatisk filosofi för LCA. Att prioritera den praktiska nyttan och effekterna av LCA utgör ett alternativ till djupt rotade övertygelser om att LCA främst handlar om vetenskaplig trovärdighet. En pragmatisk filosofi förklarar varför LCA-praktik ser olika ut, eftersom den anpassas för olika syften och kontextuella förhållanden. Snarare än att vara uttryck för subjektivitet eller oförmåga, stödjer ett pragmatiskt synsätt uppfattningen att justeringar i LCA-baserad praktik kan vara giltiga svar på möjligheter, begränsningar och ambitioner i tillämpningssammanhanget. Avhandlingen drar slutsatsen att en pragmatisk filosofi kan stödja LCA-forskare, -analytiker, och -användare i att bli mer lyhörda för praktiska förutsättningar för att hantera produkters miljöpåverkan inom och utanför byggsektorn.

Nyckelord: Livscykelanalys, LCA, byggande, pragmatism, praktik, användbarhet, trovärdighet

List of Publications

INCLUDED PAPERs

This dissertation is based on the work contained in the following publications:

I. Beemsterboer, S., Baumann, H., & Wallbaum, H. (2020). Ways to get work done: a review and systematisation of simplification practices in the LCA literature. *The International Journal of Life Cycle Assessment, 2* 2154-68. doi:10.1007/s11367-020-01821-w

II. Beemsterboer, S., Baumann, H., & Wallbaum, H. (2025). The myth of informed decision-making: explaining the substantive effectiveness of LCA use in a building product development project. *The International Journal of Life Cycle Assessment.* doi:10.1007/s11367-025-02472-5

III. Beemsterboer, S., Baumann, H., & Wallbaum, H. (n.d.). The influence of legislation-driven life cycle assessment: a cross-case analysis of LCA-based practices in four Swedish building companies between 2017 and 2025. *Manuscript*.

CONTRIBUTION REPORT

The author of this dissertation has made the following contributions to the included papers.

I. Sjouke Beemsterboer developed the original research idea, carried out the review, conducted the analysis, and wrote the first and subsequent draft versions of the text. The coauthors have contributed with supervision and suggestions for improving draft versions of the text. Henrikke Baumann contributed to the development of the original research idea.

II. Sjouke Beemsterboer developed the original research idea, carried out the empirical research, conducted the analysis, and wrote the first and all subsequent draft versions of the text. The coauthors have contributed with supervision and suggestions for improving draft versions of the text.

III. Sjouke Beemsterboer developed the original research idea, carried out the empirical research, conducted the analysis, and wrote the first and subsequent draft versions of the text. The coauthors have contributed with supervision and suggestions for improving draft versions of the text.

ADDITIONAL PUBLICATIONS

The following scientific publications are related to the topic but are not part of this dissertation:

A. Beemsterboer, S. (2019). Simplifying LCA use in the life cycle of residential buildings in Sweden. (Licentiate thesis). Chalmers University of Technology, Gothenburg.

B. Koch, C. & Beemsterboer, S. (2017). Making an engine: Performativities of building formation standards. Building Research & Information, 45(6), 596-609. doi:10.1080/09613218.2017.1301745

C. Dijk, M., de Kraker, J., van Zeijl-Rozema, A., van Lente, H., Beumer, C., Beemsterboer, S., & Valkering, P. (2017). Sustainability assessment as problem structuring: three typical ways. Sustainability Science, 1-13. doi:10.1007/s11625-016-0417-x

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E. Verbong, G., Beemsterboer, S. & Sengers, F. (2013). Smart grids or smart users? Involving users in developing a low carbon electricity economy. *Energy Policy 52*, 117-125. https://doi.org/10.1016/j.enpol.2012.05.003

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Research published in conference proceedings that are referenced in Scopus or Web of Science:

F. Beemsterboer, S., Baumann, H. and Wallbaum, H. (2020) Bridging the gap between assessment and action: recommendations for the effective use of LCA in the building process. Proceedings of the World Sustainable Built Environment conference: Beyond 2020. Gothenburg: June 9-11. IOP Conference Series: Earth and Environmental Science 558 022007. doi:10.1088/1755-1315/588/2/022007

G. Beemsterboer, S. and Koch, C. (2017) A Human Touch: Examining the Roles of Middle Managers for Innovation in Contractors In: Chan, P W and Neilson, C J (Eds.) Proceeding of the 33rd Annual ARCOM Conference, 4-6 September 2017, Cambridge, UK, Association of Researchers in Construction Management, (pp. 430-439).

H. Beemsterboer, S., Hallgren, J., Olsson, R., Koch, C. (2017). Too complex to standardise? A case study of a socially loaded pier inspection process at the port of Gothenburg. In M, Buser, G. Lindahl and C. Räisänen (Eds.) Proceedings of the 9th Nordic Conference on Construction Economics and Organization. June 12-14, Gothenburg, 318-28.

I. Beemsterboer, S. and Koch, C. (2016). Building Information Standards: Big Data Technologies Prevented from Becoming Big in Building. In: P W Chan and C J Neilson (Eds.) Proceedings of the 32nd Annual ARCOM Conference, 5-7 September 2016, Manchester, UK, Association of Researchers in Construction Management, Vol 1, 83-92.

Research presented at conferences without published conference proceedings:

J. Beemsterboer, S., Baumann, H., & Wallbaum, H. (2024). Towards a more effective use of LCA in industry: a qualitative case study of a building product development project. Presentation at the 26th SETAC Europe LCA symposium, Gothenburg, October 21-23.

K. Beemsterboer, S., Baumann, H., & Wallbaum, H. (2020). Juggling time zones – between project deadlines, data work, and environmental impacts in the building life cycle. Presentation at the Data as Relation conference, Data times: immediacies, lifecycles, forgettings. Copenhagen, December 11.

L. Beemsterboer, S., Baumann, H. & Wallbaum, H. (2019). Integrating LCA in planning, design and construction practices for new multifamily residential buildings in Sweden. Poster presented at the 9th International Conference on Life Cycle Management. Poznan, September 1-4.

OTHER

M. Beemsterboer, S., Baumann, H., & Wallbaum, H. (2020). Flera sätt att förenkla LCA för flerbostadshus. *Bygg & Teknik, 6*.

Contents

Preface

Sometimes life takes you on a journey that is impossible to foresee, leading to a destination and over a path that goes well beyond the imagination of the person who is walking it. When I started my PhD studies, I certainly could not have imagined the path that would lead me here. Looking back, there are many moments and people to treasure.

First, I would like to thank the building professionals and LCA practitioners who donated their time and thoughts to my PhD studies. The experiences that you have shared with me form the empirical core of this dissertation. In addition, this research has been made possible by generous grants from the Development Fund of the Swedish Construction Industry (SBUF #13292, #13839) and from the Swedish National Board of Housing, Building and Planning (Boverket, SFS 2018:199). It gladdens me to see that there has been an interest in funding practice-oriented LCA research.

A special thank you is reserved for my supervisors Henrikke Baumann and Holger Wallbaum. Holger, it has been a privilege to be part of the inspiring research group you have cultivated. Your engagement towards shaping a stimulating research environment as well as a more sustainable building sector has been truly motivating. Kikki, from the beginning of my time in Gothenburg, you have been an intellectual role model. When I first started reading your Hitchhiker's guide, I could not have imagined that you would one day become my supervisor. I am deeply thankful for all the thought-provoking discussions and your relentless support throughout the years!

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Finally, Valbona! I would never have embarked on this part of the journey if it were not for you, and it is quite possible that I would not have gotten this far without you by my side. Thank you for always cheering me on and inspiring me to give my best. Your presence has made this journey so much more rewarding. Nästan där!

Sjouke Beemsterboer

Gothenburg, August 2025

1 Introduction

Life cycle assessment (LCA) is a method used to compile, quantify, and evaluate the environmental burdens of resource use and environmental emissions resulting from products and services. By adopting a life cycle perspective, LCA aims to avoid burden shifting between different parts of the product life cycle (ISO, 2006a). LCA has developed over time to become a respected academic and professional field with close relations to other areas of industrial ecology. Currently, LCA is a central method for producing knowledge about the environmental impacts of goods and services, underlying countless initiatives in science, industry, and society in support of more environmentally sustainable forms of production and consumption. Importantly, the ambitions of LCA are to understand *and* address product environmental impacts (c.f. ISO, 2006a).

Understanding the potential environmental impacts associated with product systems is not a straightforward task. In modern society, even simple products or services derive from complicated product systems containing many different activities, which are frequently carried out by organisations and actors that are spread out geographically and temporally. Assessing the environmental burdens of a simple product quickly covers a few thousand resource flows and emissions, contributing to a wide range of environmental impact categories through complex cause-effect pathways. Given the centrality of companies in production processes, LCA practitioners are frequently dependent on these organisations to gain access to the object of study and to the product data required to carry out LCAs (Baumann & Tillman, 2004; Bjørn, Owsianiak, Molin, & Hauschild, 2018; Freidberg, 2015).

The close interaction with commercial organisations combined with the complexity of product life cycles has historically given rise to concerns about the validity of LCA results. Comparative analyses have shown that LCA studies evaluating the same product alternatives – e.g. types of drink packaging systems – could have very different outcomes (Bjørn et al., 2018). While variation in LCA outcomes may in part be explained by legitimate methodological choices as well as differences in production systems (Ekvall, 1999), there have also been allegations that LCA was being misused a 'hired gun' to produce results that were desirable to commercial and sectoral interests (c.f. Baumann & Tillman, 2004).

Given the difficulty in ascertaining whether LCA results are true expressions of product environmental impacts and the presence of actors with commercial interests, there has been a historic tendency to defend the credibility of LCA by developing and emphasising the scientific character of the method. Science-based developments in LCA have been aimed, amongst others, towards reducing the space for subjectivity through a data-driven approach and methodological standardisation (Bjørn et al., 2018; Hertwich, Hammitt, & Pease, 2000; Klöpffer, 2012), to prioritise a scientific-approach and support comprehensive, consistent, and transparent assessments (ISO14040), to support rational decision-making (e.g. Laurin et al., 2016), as well as scientific and mathematical rigour in LCA (e.g. Finkbeiner, Roche, & Holzapfel, 2025; Heijungs, 2024). Quite literally, concerns about scientific credibility are about gaining authority for LCA methods, outcomes, practices, and the field as a whole by connecting them with the practices and norms of science.

Although scientific ambitions have been considered to aid the credibility of LCA knowledge, it has been recognised that a too strong focus on scientifically legitimate practices may not be practically useful for addressing product environmental impacts (Baitz et al., 2013; Freidberg, 2015; Rex, Fernqvist, & Ryding, 2020). A classic example here is product design, where the results of relatively accurate ex-post LCA studies typically come too late to influence the design process (Baumann & Tillman, 2004; Bhander, Hauschild, & McAloone, 2003). Similarly, complex environmental problems have been shown to be difficult to resolve by scientific information alone because multiple legitimate problem frames coexist, each supported by credible evidence (Dijk et al., 2017; Hisschemöller & Hoppe, 2001; Tukker, 1999, 2000). Rather than just providing scientific information to rational decision makers, some have argued that LCA practitioners need to understand their role in complex decision processes in industry (c.f. Blass & Corbett, 2018; Vermeulen, 2006).

Furthermore, the close relation with companies also provides opportunities for LCA practitioners to address product environmental impacts. Companies are frequent commissioners of LCA studies as well as attractive users of LCA outcomes owing to the potential power these organisations have to improve the environmental performance of products. Hence, to satisfy the twin-ambitions of understanding *and* addressing potential product environmental impacts, LCA practitioners are caught in a struggle to produce knowledge that is both a credible representation of real impacts and practically useful to those actors that can reduce those impacts (Baitz et al., 2013; Freidberg, 2015).

The tension between scientific credibility and usefulness presents a complicated challenge for LCA practitioners and the LCA community. Here the term practical utility will be used to refer to the usefulness and effectiveness of LCA in the context in which it is practised[1]. Even if there are important reasons for safeguarding the scientific credibility of LCA, there is no ultimate justification for supporting scientific values over other practical purposes and effects of LCA for analysts, decision-makers, politicians, engineers, consumers, and so on. Instead, by directing LCA practices toward more complete, consistent, and accurate knowledge, rather than focusing on what works in practice, a normative orientation toward scientifically credible LCA knowledge may unintentionally harm the usefulness of LCA for understanding and addressing product environmental impacts (c.f. Lazarevic, 2018).

To understand the importance of practical utility in LCA, is crucial to critically examine how LCA works in real-world situations, where different practical concerns, conditions and opportunities shape the application and use of the method. By studying how LCA works in a practical context, it becomes possible to see the limits of scientific credibility as a guiding principle. Currently, attempts to balance scientific credibility and practical utility are perceived to be hindered by an imbalance in the mainstream LCA discourse. Compared with the vast scientific literature on LCA, relatively few studies have analysed how LCA actually works in practical contexts (e.g. Baumann, 1998; Frankl & Rubik, 2000; Freidberg, 2015; Lazarevic & Martin, 2018; Niero et al., 2021; Rex et al., 2020).

One of these practical contexts is connected to sustainable building practices. In the most recent IPCC report, buildings were estimated to be responsible for approximately 21% of global GHG emissions in 2019 – i.e. 12 Gt CO_2-eq (Cabeza et al., 2022). Buildings are composite products whose environmental performance is strongly influenced by the volume of building materials and by operational energy demands during their long use phase (Lasvaux et al., 2017; Röck et al., 2020). Notwithstanding their global impact, buildings are planned, designed, and constructed in individual building projects to align with local market conditions and the physical conditions of a building site (Dubois & Gadde, 2002; Winch, 2010).

In recent years, LCA has become a rapidly growing practice for assessing building environmental performance, with a corresponding growth in scientific literature (Fnais et al., 2022; Roberts, Allen, & Coley, 2020). Similar to other product domains, research on building LCA has focused especially on producing scientifically credible information about building environmental impacts building, and by developing

[1] Although there is some degree of overlap, the more pragmatic notion of *practical utility* adopted in this dissertation should not be confused with *utilitarianism.* Utilitarianism is a normative ethics associated with Bentham and John Stuart Mill, which considers human happiness or pleasure as an absolute measure by which to judge the consequences of actions (Driver, 2022; Russell, [1946] 2004). Although concerns of practical utility may contribute to pleasure or happiness, they do not have to as there are also other practical purposes and effects.

methods and tools that allow others to do so (e.g. Hansen et al., 2023; Hollberg, Genova, & Habert, 2020; Lasvaux et al., 2017; Malmqvist et al., 2018). Considering the limited empirical attention given to how LCA is practised by actors in building industry (c.f. De Wolf, Pomponi, & Moncaster, 2018; Francart, Polycarpou, Malmqvist, & Moncaster, 2022), it remains ambiguous whether a scientific focus on environmentally credible information is practically useful for understanding and addressing building environmental impacts.

1.1 Aim and objectives

To better understand the relevance of practical utility for LCA, this dissertation examines how LCA works in the practical context of sustainable building. Three particular aspects of practices have been examined that make visible the tension between practical utility and scientific credibility in LCA: simplification strategies (Paper I), LCA use in a development project (Paper II), and the evolution of LCA-based practices in building companies responding to legislation on building climate declarations (Paper III). In particular, these aspects are explored in the empirical setting of Swedish building companies between 2017 and 2025.

On the basis of the findings of these studies, this dissertation explores the potential of making a case for a pragmatic philosophy of LCA. Pragmatism – as explained in Chapter 3 – is a purpose-oriented philosophy that associates the value of knowledge with the practically conceivable effects it may have on conduct (De Waal, 2021). By relating concerns of practical utility in LCA to a more established philosophical tradition, this dissertation aims to contribute to a more balanced discourse and practice of LCA.

The following questions are addressed in this dissertation:

- RQ 1. What LCA practices can be empirically observed in the studied Swedish building companies, and how do these empirically observed practices relate to established scientific norms in the LCA community?
- RQ 2. What conclusions can be drawn from the empirical findings with respect to the challenge of balancing scientific credibility and practical utility in LCA?
- RQ 3. What is the potential for a pragmatic philosophy in LCA?

By exploring the potential for a pragmatic philosophy in LCA, a case is made for recognising the influence of practical considerations related to the purpose and context of LCA studies and other LCA-based practices. This work is rooted in early discussions on how LCA should develop as a science and a field of practice (e.g. Allenby, 1998; Ehrenfeld, 1997; Hertwich et al., 2000), and especially in those contributions that empirically analysed LCA practices in specific contextual settings (e.g. Baumann, 1998; Frankl & Rubik, 2000; Heiskanen, 2000, 2002; Tukker, 1999, 2000). The research developed from an observed tension between credible and useful knowledge in LCA practices, eloquently articulated by the ethnographer Sussane Friedberg (Freidberg, 2015), yet also visible in accounts of LCA practitioners (Baitz et al., 2013; Rex et al., 2020) as well as popular textbooks on LCA (e.g. Baumann & Tillman, 2004; Guinée, 2002; Hauschild, Rosenbaum, & Irving Olsen, 2018).

Notably, renewed attention to the subject matter finds support in the ISO 14040 standard (ISO, 2006a), which relates methodological choices to the application context and explicitly states that LCA intends to understand *and* address potential product environmental impacts. A deeper understanding of the practicalities of adapting LCA to its use and application contexts can support improving the usefulness of LCA in sustainable building practices and other domains.

1.2 Outline

Having briefly introduced the topic, research problem, and research aim, this section provides an outline of the remaining chapters.

- Chapter 2 presents a background on the research domain. The chapter starts by introducing LCA as a science-based method (2.1) and by describing the development of building LCA in relation to other environmental building practices (2.2). Thereafter, the chapter explores the importance of context for LCA practices (2.3), suggesting that LCA research and practices can benefit from balancing scientific credibility and practical utility more explicitly (2.4).

- Chapter 3 introduces philosophical, theoretical, and methodological considerations that frame the thesis. The chapter introduces pragmatism as a (scientific) philosophy that relates the value of knowledge to its practical effects (3.1), discusses substantive and relational strands of practice theory (3.2), and presents theoretical concepts and methodological lessons drawn from existing research on science and technology studies (STS) (3.3). The chapter ends by tying together useful lessons that can be drawn from these different research domains for studying LCA in practice (3.4).
- Chapter 4 introduces the research design and trajectory (4.1) as well as the research methods that were employed in this dissertation (4.2).
- Chapter 5 summarises the results of the research papers included in the dissertation. The sections focus on simplification strategies in LCA (Paper I, 5.1), substantive effectiveness from LCA use in a development project for a standardised building design (Paper II, 5.2), and the evolution of LCA-based practices in building companies responding to legislation on building climate declarations (Paper III, 5.3).

- Chapter 6 presents an analysis of the research findings aimed at answering the research questions addressed in this thesis. It includes an examination of the studied building LCA practices (6.1) and the tension between scientific credibility and practical utility (6.2), in order to make a case for a pragmatist philosophy in LCA (6.3).
- Chapter 7 continues with a discussion of the research outcomes. It discusses limitations of the conducted research (7.1) and its main contributions (7.2). The chapter concludes by drawing implications of the research outcomes for LCA research, practice and teaching (7.3) and identifying avenues for future research (7.4).

2 Background

This chapter presents a background on the current state of knowledge about the research domain. It introduces LCA and its main concepts (2.1) and describes the development of building LCA in relation to other environmental building practices (2.2). Thereafter, the chapter surveys existing knowledge on the importance of practical conditions and contextual factors in shaping LCA practices (2.3), affecting the balance with scientific credibility in LCA (2.4).

2.1 Introducing LCA as a science-based method

Life cycle assessment (LCA) has been introduced as a method for compiling, quantifying, and evaluating the environmental burdens of resource use and environmental emissions throughout a product life cycle (ISO, 2006a). LCA produces modelled representations of real environmental burdens that are LCA is used with two ambitions in mind: (1) to better understand the potential environmental impacts of product systems and (2) to address these impacts (ISO, 2006a).

The product life cycle perspective in LCA aims to avoid burden shifting between different parts of the product life cycle if it leads to sub-optimal solutions. In a similar vein, LCA studies are strongly recommended to assess environmental burdens across a range of impact categories relevant to the goal and scope of a study (ISO, 2006b). Given that burden shifting may even take place beyond the environmental domain, LCA can be combined with life cycle cost assessment (LCC) and social life cycle assessment (SLCA) into a life cycle sustainability assessment (LCSA) (UNEP, 2011; Valdivia et al., 2021).

The process of performing LCA is typically understood in terms of the four phases of the LCA procedure (see ISO, 2006a), providing structure to the activities carried out in LCA studies.

1. Goal and Scope: establishes the intended application, audience, and reason for carrying out the study, as well as the methodological scope in terms of the functional unit and system boundaries in order to define the breadth, depth, and detail of a study.
2. Life Cycle Inventory analysis (LCI): develops a life cycle inventory model containing a flow chart of individual processes in a product system, to which input data on resource use and output data on emissions and waste are connected. The LCI phase typically results in a quantified inventory of relevant environmental loads of a product system.
3. Life Cycle Impact Assessment (LCIA): converts the environmental loads compiled in the inventory analysis into an assessment of environmental impacts.
4. Interpretation: evaluates the outcomes from the LCI and LCIA against the goal and scope to identify significant results and tests the robustness of these results.

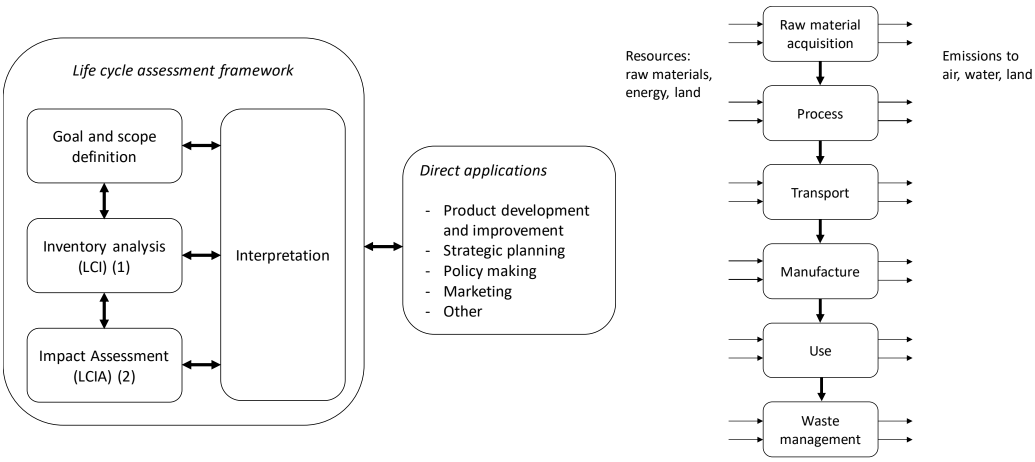

Figure 1: Four stages of an LCA procedure in ISO14040 (ISO, 2006a) and the resulting life cycle model (Baumann & Tillman, 2004)

Several iterations of the four phases of LCA are typically recommended in order to gradually improve the quality of the LCA (Baumann & Tillman, 2004; Guinée, 2002; Klöpffer & Grahl, 2014). Additionally, the ISO 14040 standard expresses a two-way interaction between LCA and the context of application. This clearly indicates that the practical application context is expected to influence how LCA is carried out and that LCA methodological choices, in turn, influence the usefulness of LCA in the application context (Bey, 2018).

While the structure of the LCA procedure is principally the same for any product system, the life cycle model is specific to the product system studied. To improve coherence between LCA studies, many sectors have developed methodological standards that structure the common elements of a product system. Figure 2 gives an overview of the main stages in the life cycle model of a building following the EN 15978 standard (CEN, 2011).

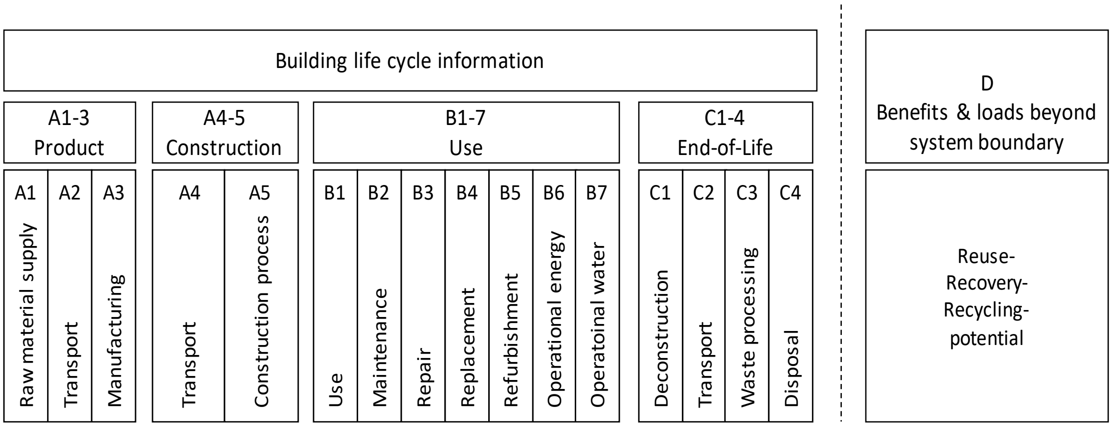

Figure 2: Building assessment information in EN 15978 (CEN, 2011)

Concerns of scientific credibility in LCA

As mentioned in the introduction, the LCA community has historically been concerned with the scientific credibility of LCA, inspiring developments and discourse that emphasise the scientific-basis of the method. Concerns with scientific credibility in LCA follow from the difficulty of producing objective, factual, and accurate knowledge. The empirical complexity of product life cycles and their environmental impacts has made claims about strictly objective knowledge difficult to maintain. This situation is worsened by the recognition that subjective or value-laden choices may influence LCA outcomes (Freidberg, 2018). Although subjective elements have frequently been viewed as an intrinsic part of environmental and other assessment methods (c.f. Beemsterboer & Kemp, 2016; Bond, Morrison-Sounders, & Howitt, 2013; Guba & Lincoln), there have been fears that acknowledging the role of subjective elements in LCA may reduce the scientific value of its outcomes (c.f. Klöpffer, 1998).

In defending the scientific credibility of LCA as well as other areas of industrial ecology, some researchers have argued for separating scientifically legitimate methodological choices from what are perceived to be undue subjective influences (Allenby, 1999; Marsmann et al., 1999). In response, others have cautioned that such a separation is arbitrary as LCA and industrial ecology are inherently normative (Boons & Roome, 2000; Finnveden, 1997).

Supported by insights from the philosophy and sociology of science, Hertwich *et al* (2000) proposed redefining objectivity and rationality in LCA as being methodologically consistent with the *goal* of a study. While advancing a systematic and rational approach, Hertwich *et al* moved away from ambitions for objective knowledge as independent from the practical context in which it is produced. Instead, it was proposed that the quality of LCA knowledge should be understood in relation to meeting the *objectives* of a study, and hence, relative to contextual aspects such as purpose and intended use.

While Hertwich *et al* presented a workable solution by defining scientific credibility as being relative to the objectives of a study, the suggested rational approach to goal-oriented methodological choices is not unproblematic in LCA applications. For example, Tukker (1999) highlighted limitations of a rational approach in situations where decision-makers face complex environmental problems. On the basis of a detailed analysis of environmental controversies surrounding chlorine in the Netherlands and polyvinyl chloride (PVC) in Sweden, Tukker showed how complex environmental problems defied rational solutions as each controversy carried competing problem frames that were supported by legitimate concerns and environmental evidence.

The ambiguous relationship between scientific ambitions in LCA and its everyday practice, here associated with Hertwich *et al* and Tukker, has found its way into ISO 14040/44 standards (ISO, 2006a, 2006b). While the ISO standards prioritise a scientific approach that commits to the natural sciences, including scientifically and technically valid methods, they do not define LCA as an objective scientific method. While promoting consistent, comprehensive, transparent, and reliable knowledge, the ISO 14040/44 standards prescribe that methodological choices in LCA have to be made in relation to the goal and scope of a study and hence the application context. In addition, even though the application context is recognised to influence LCA, the ISO 14040 standard places the application of LCA results outside the scope of the standard (p.1), stating that there is "…no single solution as to how LCA can best be applied within the decision-making context" (p.19).

Definitions of LCA

Science-based ambitions in LCA have frequently coincided with what can be paraphrased as a concern for technical, quantitative, and modelled LCA outcomes. Although these elements are undeniably part of LCA, they fail to define the full scope of what is included in LCA practices (c.f. Baitz et al., 2013; Baumann, 1998; Frankl & Rubik, 2000; Heiskanen, 1997; Lazarevic & Martin, 2018; Rex et al., 2020). To comprehend how LCA works in everyday practice, it is not sufficient to focus on the reported outcomes of LCA studies. Starting from a classical distinction between the LCA procedure and the LCA model (c.f. Baumann, 1998), it is possible to expand the definition of LCA. Table 1 presents four different views on what counts as an LCA – i.e.

(1) an LCA report, (2) an LCA study outcome, (3) an LCA study process, and (4) LCA practices.

The LCA can be viewed as (1) the reported outcome of an LCA study. This allows the LCA to be studied largely independently of the spatial–temporal context in which it was produced. LCA reports are the most easily accessible version of LCA, as the document empirically matches the phenomenon. At the same time, an LCA report is by definition a restricted version of the LCA study. Although good LCA reports communicate what are deemed the most important aspects of an LCA study, they do not communicate the study in its entirety.

The LCA study outcome (2) is the underlying phenomenon on which an LCA report is based. It includes all the methodological choices, data, models, calculations, and interpretations that are part of the LCA. In practice, LCA reports frequently do not communicate the full inventory model, let alone all the underlying data and assumptions. Located on internal computer servers and the heads of the analysts involved, the LCA study as a phenomenon is more difficult to access than the communicated LCA report.

Table 1: Different views on what counts as LCA

	Definition	*Included*
1	LCA report	Relevant outcomes of an LCA study Relevant methodological choices
2	LCA study outcome	All outcomes of an LCA study All outcomes of each LCA phase: goal and scope, LCI, LCIA, interpretation All methodological choices in each LCA phase
3	LCA study process	All activities and processes involved in the four phases of an LCA Interaction with commissioner, data-providers, and other relevant stakeholders Direct supporting activities
4	LCA practice	Carrying out an LCA study Using an LCA report, LCA outcome, and LCA process for learning, decision-making, LCT, LCM, and other life cycle practices. Direct and indirect supporting activities, including the organisation of LCA capacity and related interactions

Next, LCA can be viewed as (3) the process of carrying out an LCA study. In addition to being situated in a specific spatial context, the process of carrying out an LCA study is also a temporally transient phenomenon – i.e. LCA activities take place at a specific moment in time. Capturing the process of carrying out an LCA requires access to the specific spatial and temporal context in which it is practised.

Finally, (4) LCA practice includes the entire range of activities and actors involved in carrying out LCA, using LCA in decision-making and other activities, organising LCA capacity, organisational learning, life cycle thinking (LCT), life cycle management (LCM), and other life cycle practices. Compared with the process of carrying out LCA, LCA practices tend to involve a wider range of activities and practices across a larger spatial and temporal domain. Given the wide scope of activities and actors involved, it is also possible to speak of *LCA-based practices*.

Although LCA can empirically include all four definitions simultaneously – a report, study outcome, study process, and practice – LCA researchers and practitioners frequently adopt a more restricted definition of what is considered a part of LCA. While reducing LCA to its reported or modelled outcomes may benefit a quantitative understanding of product environmental impacts, it is only of limited value to understand how LCA works in particular practical settings.

2.2 LCA as a method for sustainable building practices

This dissertation examines LCA in the context of sustainable building practices. Historically, the introduction of LCA to support environmentally conscious building practices has been a rather novel development in the long-standing relationship between buildings and the natural environment. When discussing the development of LCA as a method for sustainable building practices, it is sensible to briefly introduce the historical evolution of environmental concerns in building. Some key milestones in this evolution are presented in *Box 1* at the end of this section.

Environmental concerns in building practices

In pre-modern societies, environmental concerns in building practices were typically strongly influenced by the local availability of natural resources for constructing and, if needed, heating buildings (Addis, 2007; Ponting, 2007). With the rise of modern industrial societies, building practices were becoming increasingly less constrained by local resource use and could instead be oriented towards improving the quality of the indoor living environment in terms of hygiene, comfort, and daylighting (Shove, 2003). Furthermore, an economic rationalisation of construction materials made an increase in building production possible and satisfy societal demands for better housing conditions. In Sweden, the height of modern house building was reached with the iconic ‘million homes programme’ (*miljonprogrammet)*, a government-led initiative to build one million residential units between 1965 and 1975.

From a European perspective, the energy crisis of the 1970s marked a change in the building sector’s relation to the natural environment. Although sparked by political turmoil, the resulting shortage of petroleum supported a renewed understanding that natural resources were in fact finite (c.f. Meadows, Meadows, Randers, & Behrens, 1972). As most buildings have a service life time between 30 and 100 years, energy demands can quickly accumulate in a building stock that is poorly insulated and has inefficient heating technologies. To reduce operational energy use, the sector has long aimed at adopting technical solutions by adding insulation materials, double- and triple-glazed windows, and installing more efficient heating technologies (e.g. Bokalders & Block, 2004; Guy & Shove, 2000; Moncaster, 2012). Practically, ambitions to reduce operational energy usage culminated in the development of passive houses as well as the introduction of the first EU energy performance of building directive (EPBD) (EU Directive 2002/91/EC).

Despite framing energy use as a central environmental concern in building, other environmental and sustainability considerations have also been present in sustainable building practices. For example, the use of asbestos, hazardous solvents, softeners, and emulsifiers in paints and sealing compounds have long been recognised as threats to human well-being and the natural environment (Bokalders & Block, 2004). In this context, insulation measures have not always been viewed positively. For example, as early as the 1980s, a debate emerged on potential negative side effects from insulation measures on human well-being due to a reduction in natural drafts in buildings (sick-building syndrome) (Bokalders & Block, 2004).

Ambitions to develop a more comprehensive approach to building environmental and sustainability concerns took a leap forward when BREEAM released its first dedicated building environmental certification scheme in the UK in 1990. The success of BREEAM was followed by the subsequent development of building environmental certification schemes in a host of different countries, including the United States (LEED), Japan (CASBEE), Germany (DGNB), France (HQE), and Sweden (Miljöbyggnad). Rather than restricting building sustainability to operational energy use, voluntary certification schemes tended to rely on a point-based system to score a building’s performance across a range of environmental or sustainability conditions. The success of these schemes was closely connected to the symbolic value of owning or renting an environmentally certified building and hence to the additional economic revenue that could be gained from selling or renting the property (Lützkendorf & Lorenz, 2011). Simultaneously, the voluntary and market-based logic supporting building environmental certification schemes implies that many building projects have remained unaffected by this practice. In 2018, the European Commission introduced Level(s), a harmonised framework for green building certification schemes (European Commission, 2025).

Introducing building LCA as a science-driven practice

Compared with the traditional focus on local resource availability, operational energy use, and building certification schemes, the introduction of LCA as a method in sustainable building practices has been relatively recent. Although early LCA studies on packaging date back to the 1970s (Baumann & Tillman, 2004), it was not until the second half of the 1990s that the first LCA studies of buildings were published (Cole & Kernan, 1996; Feist, 1996; Suzuki & Oka, 1998; Winther & Hestnes, 1999). In line with the dominance of energy-related thinking in the building industry, early LCA studies focused heavily on building life cycle energy use.

In Sweden, a landmark study was carried out by Adalberth (1995), who assessed the primary energy use connected to the product life cycle of three single-family residential buildings. These early studies confirmed the importance of building operational energy use, estimating that this stage was responsible for 70–90% of building life cycle energy use in typical buildings with an assumed life span of 50 years. In addition, these authors reported that the relative share of energy embedded in building materials increased quickly when building operational energy use was reduced (Cole & Kernan, 1996; Feist, 1996; Suzuki & Oka, 1998; Winther & Hestnes, 1999). These conclusions legitimised the use of LCA as a relevant method to assess the environmental impacts of buildings.

Early applications of the LCA methodology to buildings were perceived to be challenging because of the limited availability of life cycle inventory data for building materials and products. It was only during the 1990s that LCI data for different construction materials were systematically produced (Chae & Kim, 2023). A milestone was the release of the EcoInvent database in 2003, which produced commercially available generic LCI data for most basic building materials. At the national level, the development of dedicated LCI datasets has been uneven. For example, the German Federal Ministry for Housing, Urban Development and Building released its *Ökobaudata* as early as 2013 (Chae & Kim, 2023). In contrast, the Swedish National Board of Housing, Building and Planning (Boverket) released its *klimatdatabas* for construction materials and products as recently as 2021.

LCA applications were subsequently burdened by a range of practical problems connected to building companies (Beemsterboer, 2019). A lack of demand for LCA in building projects has frequently been identified as a reason for the slow adoption of LCA in building companies. In a practical context, the usefulness of LCA for building projects was not self-evident. LCA was initially perceived as a complicated and time-consuming activity, which was difficult to sell to individual building projects. In this context, the results of LCA studies typically became available only after the project was completed. Furthermore, the reality of ex-post LCA results contrasted with the industry axiom that improvements in building design are best introduced early in building projects (c.f. Beemsterboer, 2019). In light of these issues, it is not surprising that most building companies remained faithful to energy efficiency measures and voluntary certification schemes when addressing environmental issues in their building projects.

In the absence of a clear industry-led practice, the initial adoption and diffusion of building LCA has, notably, been driven by scientific researchers at universities and other research institutes. Initially, case studies were carried out and compiled to identify environmental hotspots in building elements as well as life cycle phases. Several of these studies confirmed earlier conclusions that a focus on reducing operational energy use was increasingly inadequate in lower energy or passive houses (Blengini & Di Carlo, 2010; Brunklaus, Thormark, & Baumann, 2010; Wallhagen, Glaumann, & Malmqvist, 2011). Instead, the LCA identified the relevance of upstream construction materials, especially the load bearing system, for building environmental impacts (i.e. product stages A1-3 according to EN15978:2011). Although several building LCA studies include a wider range of environmental impact categories, analytic attention is nearly exclusively limited to GWP or primary energy use.

With the increasing number of published case studies, LCA researchers have started carrying out meta-studies of larger sets of buildings with the intention of drawing generic conclusions from comparisons of individual cases. Attention has been given to building environmental hotspots – e.g. embodied versus operational carbon emissions (Birgisdottir et al., 2017), design improvement measures – e.g. changes in material usage in the structural system (Malmqvist et al., 2018; Saade, Guest, & Amor, 2020), and the development of reference values for different building types (Lasvaux et al., 2017; Malmqvist, Borgström, Brismark, & Erlandsson, 2023).

Similar to LCA studies in other domains, it has become clear that methodological choices greatly affect outcomes in building LCAs, complicating a comparison of results (Anand & Amor, 2017; De Wolf, Pomponi, & Moncaster, 2017; Rasmussen, Malmqvist, Moncaster, Wiberg, & Birgisdóttir, 2018; Saade et al., 2020). In addition, the practice of building LCAs is further complicated by the long life spans of buildings (50-100 years), lower predictability of uncertainty variables and parameters, unique characteristics of each building, the quantity of different materials and processes, varying life spans, and evolution of building functions over time (Buyle, Braet, & Audenaert, 2013). Although methodological choices remain an issue of concern, harmonisation has been sought through a European norm specifying methodological rules for assessing the environmental performance of buildings (EN 15978:2011) (CEN, 2011).

In addition to exemplar case studies to demonstrate the technical feasibility of the method, LCA researchers have aimed to improve the adoption of LCA in building practices by developing novel LCA tools and techniques. Initially, a range of simplified LCA tools were developed to reduce the efforts required to carry out building LCAs (Malmqvist et al., 2011; Zabalza Bribián, Aranda Usón, & Scarpellini, 2009). More recently, building LCA research has started to promote BIM-LCA as a way to promote LCA use in building projects, aiming for a seamless handling of building resource data from digital models developed in building projects (Hollberg et al., 2020; Najjar et al., 2022; Röck, Hollberg, Habert, & Passer, 2018).

Frequently, these tools target early building design practices, where reductions in the environmental impacts of buildings are considered easiest to achieve (Hansen et al., 2023; Meex, Hollberg, Knapen, Hildebrand, & Verbeeck, 2018; Soust-Verdaguer et al., 2022). In this context, the use of parametric optimisation techniques in building LCA could help choose efficient design options (Kiss & Szalay, 2020). In addition, dynamic LCA approaches have been developed to better account for evolving parameters such as biogenic carbon, decarbonisation of the energy supply, and changes in the building stock (Slavkovic & Stephan, 2025).

Regulations and the development of an industry-based building LCA practice

Despite impressive scientific developments, it has been difficult to promote the use of LCA in building companies on the basis of the scientific merit and promise of the methodology alone. A lack of LCI data, methodological inconsistencies, and reliable benchmarks have been identified to hinder the development of an industry-based building LCA practice (De Wolf et al., 2017). In addition, limited LCA use in the building industry has been related to the lack of clear market demand, which is typically associated with an absence of client and regulatory requirements (e.g. Francart, Larsson, Malmqvist, Erlandsson, & Florell, 2019; A. Moncaster, Malmqvist, Polycarpou, Anderson, & Francart, 2023). Conversely, the increasing spread of EPDs for construction products (c.f. Passer et al., 2015), methodological standardisation, climate targets, and building certification schemes were identified as solutions in support of LCA implementation in the building industry (De Wolf et al., 2017).

Although LCA-based climate calculations have become part of several voluntary building environmental certification schemes (Anand & Amor, 2017; Moncaster & Malmqvist, 2020), the breakthrough for an industry-based LCA practice can also be related to regulatory drivers. In the early 2020s, several European countries started demanding LCA-based calculations to be carried out for new building projects, e.g. the Netherlands, France, Danmark, and Sweden (Barjot, 2024; Boverket, 2023; MTE, 2024; Rijksoverheid, 2024; Rikstinget, 2021). In Sweden, public authorities introduced mandatory declarations of climate impacts for all new building projects over 100 m^2 in 2022 (Boverket, 2024).

Even if the sophistication of LCA-based climate calculations remains limited compared with scientific developments in the building LCA field, these regulatory developments have created a strong demand for LCA-based climate calculations in the building industry. For example, in Sweden alone, 1041 LCA-based climate declarations were registered at the national authority in 2024 (Boverket, 2025), in contrast to an estimated global scientific output of 832 articles on LCA in the built environment in 2020 (Fnais et al., 2022). On a European level, the introduction of the EU Taxonomy introduced several LCA-based environmental objectives that have to be met for financial (capital) investments by large EU-listed companies to be classified as environmentally sustainable (EU, 2020).

Since its inception in the 1990s, building LCA has expanded and developed into a mature methodology for assessing building environmental impacts, as well as a lively subdomain of the LCA community. Currently, building LCAs includes a variety of LCA applications, including market-driven LCA practices related to certification schemes and EPDs, regulatory-driven LCA practices in climate declarations, and science-driven LCA practices. Compared with earlier environmental practices in buildings, LCA promises a novel orientation toward environmental work, expanding beyond a focus on direct energy use and semi-quantified certification schemes that have long characterised environmentally sustainable building practices.

With respect to future practices, scientific and regulatory developments are focused on expanding the application of building LCA. These developments are increasingly oriented towards the inclusion of whole-building life cycle impacts. This will make building LCAs more connected to renovation measures, end-of-life practices for construction and demolition waste (CDW), and circular design questions. Following the Danish example, several European countries are anticipating the introduction of limit values for buildings (Nordic Sustainable Construction, 2025), a topic that is also suggested as an avenue for future European regulation (Urban, Karlsson, & Nipius, 2025). While current building LCA practices are still dominated by a focus on GWP, the upcoming years are expected to expand to include other environmental impact categories in line with different European developments (EU, 2020, 2024a, 2024b).

Box 1: Overview of key milestones for LCA and sustainable building practices

1970s:	First LCA studies carried out on beverage packaging alternatives.
1990:	Environmental certification of buildings: BREEAM was launched as the first voluntary building environmental certification scheme.
1991:	Construction of first Passive house in Germany.
1995:	Appropriation of LCA method on buildings in Sweden: Early science-based LCA studies focussing on primary energy use for three single family residential buildings (Adalberth, 1995, 1997).
1997:	Methodology development LCA: ISO 14040:1997, standard defining the principles and framework for LCA. Complemented amongst others by ISO14044:2006.
1998:	Vattenfall AB produces the first EPD for electricity production from hydropower from the river Lule älv.
2000:	Methodology development LCA: ISO publishes a technical report on Type III environmental declarations (EPD), in 2006 formalised in ISO 14025:2006.
2002:	EU-legislation: first Energy Performance of Building Directive (EPBD) (Directive 2002/91/EC), introducing mandatory energy performance certificates for building operational energy use in 2006.
2003:	Database development LCA: First version of the EcoInvent database released (following BUWAL250 LCI datasets from the 1990s).
2011:	Methodology development: EN 15978:2011, European standard specifying methodological rules for assessing the environmental performance of buildings – including LCA.
2011:	Environmental certification: BREEAM introduces option to gain additional points in its voluntary building certification scheme by carrying out a simplified LCA-based climate calculation.
2012:	Methodology development: EN15804+A1, European standard specifying methodological rules for the development of Environmental Product Declarations (EPDs) for construction products developed.

2013:	Methodology development: Product Environmental Footprints (PEF). European Commission develops harmonised environmental footprint methodologies for different product categories based on LCA.
2018:	Methodology development: The European Commission introduces Level(s), a harmonised framework for green building certification schemes.
2019:	Methodology development: Update EN15804+A2: revision of standard to align with PEF, mandatory from July 2022.
2020:	EU legislation: The EU Taxonomy (Regulation EU/2020/852) introduces a reporting standard with environmental objectives that have to be met for financial (capital) investments by large EU-listed companies to be classified as environmentally sustainable. Entered into force in 2022 and 2023.[2]
2021:	Data development: The Swedish National Board of Housing, Building and Planning (Boverket) publishes the first Swedish open-access database with climate data for construction materials and products.
2021:	Swedish legislation: Swedish parliament passes a bill requiring LCA-based climate declarations to be carried out in connection with the building permit of new building projects as of 2022.
2024:	EU-legislation: Construction Product Regulation (CPR) (Regulation EU/2024/3110), prescribes the inclusion of environmental life cycle performance information for construction products in relation to obtaining a CE-mark and hence access to the EU's single market. LCA stipulations will enter into force in 2026 and 2028.[3]
2024:	EU-legislation: Revised Energy Performance of Buildings Directive (Directive EU/2024/1275). Prescribes calculation of life-cycle GWP for new buildings over 1000 m^2 by 2028, and for all new buildings by 2030.[4]

[2] LCA-related environmental objectives include climate change mitigation and adaptation (starting in 2022), water and marine resources, circular economy, pollution prevention and control, and production and restauration of biodiversity and ecosystems (starting in 2023) (Article 9, Article 27) (EU, 2020).

[3] Starting in 2026 for climate change effects (total, fossil fuels, biogenic, LULUC) and being successively expanded to include 19 environmental impact categories by 2032 (Article 5) (EU, 2024b).

[4]Additionally, the EPBD also prescribes the introduction of thresholds for operational energy use and operational GWP for new buildings by 2030 (Article 11) and introduces binding national targets for average energy performance of the national building stock – i.e. a 16% reduction by 2030 compared to 2020 (EU, 2024a).

2.3 Understanding LCA practice in the context of application

In the previous section, the evolution of building LCA was described in a sector where local resource availability, building energy performance, and voluntary certification schemes have contributed to structuring environmental building practices. Given the novelty of building LCA as an industry-based practice, relatively few studies have aimed to empirically address the relevance of practical building contexts (c.f. Brunklaus, 2008; De Wolf et al., 2017; Francart et al., 2022; Moncaster, 2012).

This section continues by introducing different elements of the practical context in which LCA is practised. While the application context is mentioned in the ISO 14040/44 standard, it remains poorly detailed (ISO, 2006a, 2006b). The remainder of this section is devoted to understanding aspects that shape how LCA is practised in practical application contexts. In particular, it covers (1) the orientation of LCA applications, (2) types of LCA use, and (3) contextual factors related to analytical resources, structures, actors, and institutions.

Orientation of LCA applications

LCA application designates a category of an LCA practice – e.g. product development, EPDs, and regulation. Classically, LCA applications have been divided into internally and externally oriented LCA applications (Baumann, 1998; Berkhout, 1996). Internally oriented LCA applications are typically directed within the organisational boundaries in which LCA is being applied. Eco-design, product development, process improvement, and research and development applications are examples of internally oriented LCA applications (Baumann & Tillman, 2004; McAloone & Pigosso, 2018; Sandin et al., 2014). Internally oriented LCA applications typically have a relatively large methodological freedom to adjust LCA activities to the specific demands of the contextual settings in which they are taking place.

Externally oriented LCA applications are directed outside the organisational boundaries in which LCA is practised. Externally oriented LCA applications include the provision of LCA-based information to consumers and businesses through EPDs, comparative assertions, and other publicly marketed LCA results (Baumann & Tillman, 2004; Frydendal, Engel Hansen, & Bonou, 2018). Additionally, it also includes compliance with governmental regulations prescribing the provision of LCA-based information (Jegen, 2024; Sala, Amadei, Beylot, & Ardente, 2021; Sonnemann et al., 2018). Given that externally oriented LCA applications are oriented outside company boundaries, they have traditionally been governed by stricter methodological rules. For example, issuing comparative assertions on the environmental performance of two products from competing companies is governed by the ISO standard and requires an independent third-party review (ISO, 2006a).

A strict division into internally and externally oriented LCA applications is complicated because LCA can serve multiple orientations and because product life cycles extend beyond corporate boundaries. Hence, internally oriented LCA applications can also address an organisation's intention to take responsibility for inputs, outputs, and emissions that lie outside company boundaries (c.f. Baumann & Tillman, 2004; Heiskanen, 2002). Life cycle activities oriented at reducing product environmental impacts quickly involve a degree of coordination between different organisations in a product chain (Bednarz et al., 2018; Boons & Baas, 1997; Nilsson-Lindén, Rosén, & Baumann, 2019; Rebitzer, 2015). For example, Testa *et al* (2017; 2022) show how companies collaborate to overcome barriers to the adoption of LCA. Jordan (2025) shows how external reporting requirements may drive internal product life cycle applications in companies.

Types of LCA use

LCA use is related to the goal or purpose that LCA has for those involved – e.g. learning, evaluating, communicating, decision-making, regulating, and strategic and symbolic uses (Baumann, 1998; Baumann & Tillman, 2004; Frankl & Rubik, 2000). These different forms of LCA use can be connected to overarching ambitions described in the ISO14040 standard – i.e. to *understand* the significance of product environmental impacts and *address* these impacts (ISO, 2006a).

Understanding the significance of product environmental impacts is frequently connected to an LCA outcome. It may involve obtaining an overview of a product system, learning about potential product environmental impacts, or comparing the environmental impacts of a product to those of other products or reference values. Attempts to improve LCA use in terms of understanding environmental impacts focus on producing high-quality LCA results, as well as LCA results that are easy for intended users to understand (c.f. Bey, 2018; Sonnemann, Gemechu, Remmen, Frydendal, & Jensen, 2015; Stucki et al., 2021).

Addressing product environmental impacts connects LCA to the decisions and activities required to make environmentally beneficial changes to product systems. Decision-making is frequently positioned as a central use of LCA related to addressing product environmental impacts (Hertwich et al., 2000; Pryshlakivsky & Searcy, 2021; Subal, Braunschweig, & Hellweg, 2024). Several scholars have pointed to the importance of better understanding the complexity of decision-making processes (Bianchi, Testa, Boiral, & Iraldo, 2022; Blass & Corbett, 2018; Vermeulen, 2006). Furthermore, research into LCM and life cycle practices has identified a wider range of activities and processes that use LCA to address product environmental impact (Bey, 2018; Nilsson-Lindén, 2018). To better understand how LCA applications and uses can differ across settings, it is worthwhile consider contextual factors influencing LCA practices.

Other contextual factors influencing LCA practices

First, a resource-based view of organisations suggests that LCA applications are shaped by the *capacities of organisations and individuals* to carry out LCA. Capacity describes the availability of analytical resources – human, financial, data, and technological – to apply LCA. Analytical resource limitations have long been identified as a challenge in LCA and have influenced developmental activities in the LCA community (Berkhout & Howes, 1997; Bey, 2018; Sonnemann et al., 2015). A continuously evolving literature of methods, frameworks, tools, and data to support LCA applications is evidence of the importance of capacity building (e.g. Cremer, Müller, Berger, & Finkbeiner, 2020; Hollberg, Vogel, & Habert, 2019; Yang & Campbell, 2017). What is less frequently discussed is how the availability of specific tools, datasets, skills, or demands will shape the direction in which LCA is applied practically by making specific types of applications easier or more difficult to perform.

Second, the pattern of LCA application is influenced by *structural aspects*, such as product type, sector, and structural elements related to the value chain and its organisations. Differences between product types may influence the organisation of production processes, which in turn influences the use of LCA in companies and sectors. For example, LCA applications on bulk commodities such as plastic granulates differ from those of more complex consumer products such as cars (Berkhout & Howes, 1997). Similarly, LCA applications differ between buildings and building materials, with the former being produced in individual projects and the latter being batch- or mass-produced (Bey, 2018).

Structural elements influence the perceived usefulness of LCA for organisations. For example, LCA was initially deemed especially suitable for large producers of final products, given the influence they have on other actors in the product chain, as well as the degree of market exposure they receive (Berkhout & Howes, 1997). The introduction of actor-based perspectives to LCA developed the view that the opportunities of actors to address product environmental impacts are related to their relative position in the structure of the value chain (Baumann et al., 2011; Berlin, Sonesson, & Tillman, 2008) and can subsequently inspire different development paths towards collaboration between organisations in a product value chain (Nilsson-Lindén, 2018; Testa et al., 2022). In particular, the interaction points between social actors and material resource flows (SMIPs) along a product value chain have been identified as structural focal points for environmental change (Baumann & Lindkvist, 2022; Lindkvist, 2018).

Emphasising the importance of product- and organisation-related structural elements in LCA applications is attractive when supporting scientific rigour in LCA. If structural characteristics determine LCA applications, it would be theoretically possible to develop LCA in a positivist direction, where outcomes would be an unfiltered representation of the object analysed. Irrespective of any such theoretical considerations, it would nonetheless remain practically difficult to know product environmental impacts given the complexity of the object studied – the product life cycle, its resource flows, emissions, and impact pathways.

A third type of contextual factors shaping the patterns of LCA application is connected to *individual and organisational perceptions and activities*. The role of individual LCA practitioners in relation to methodological preferences as well as personal ambitions to develop LCA use in organisations, including perceptions about relevant environmental problems and the usefulness of LCA in addressing these problems (Baumann, 1998). The perceptions and actions of individual LCA practitioners have been identified as especially relevant in organisational settings where LCA is a novel method (Nilsson-Lindén, Baumann, & Rex, 2019), including the interpretation of LCA findings by managers (Heiskanen, 2000). Differing interpretations, strategic choices and contingencies have been shown to result in different LCA practices between organisations that share similar structural conditions (Rex & Baumann, 2007, 2008).

A fourth type of contextual aspect shaping LCA application is the presence of *institutions* that contain a more permanent shared practice of applying LCA in a particular setting. ISO 14040 and 14044 are well-known examples of institutions that regulate LCA practices, prescribing how LCA should be carried out (ISO, 2006a, 2006b). Over time, organisations that successfully apply LCA have been shown to develop their own institutionalised ways of practising LCA (Baumann, 1998; Frankl & Rubik, 2000, Tessitore et al., 2025). Institutions develop in the context of product and sectoral structures, as well as the perceptions and actions of individuals and organisations. Hence, patterned ways of practising LCA develop, which are not predetermined by the physical and structural characteristics of the product system, nor are they a result of the individual choice of LCA practitioners. Institutionalised ways of performing LCA in particular settings continue shaping how LCA is practised once it is established even if it evolves over time.

For example, Linnanen *et al* (1995) reported that the ways in which LCA is used to support decision-making are influenced by the management culture of an organisation. Emphasising structural elements, Brunklaus (2008) concluded that municipal and cooperative housing companies could develop organisationally different approaches to tackling environmental concerns. At the same time, Rex and Baumann (2007) showed that even under structurally similar conditions, organisations can develop different ways of practising LCA, thereby emphasising the importance of individual and organisational trajectories in developing LCA practices.

This section considered how LCA applications, uses and other contextual factors shape the way in which LCA is practised. Notably, LCA applications and uses vary across different contextual settings. Understanding the multiple layers of the practical context is a competence allows practitioners to adjust LCA practices to the purposes and contextual settings in which it is practised.

In support of this issue, LCA experts have traditionally shared the competence of making choices that are suitable to the context of application through handbooks and guidelines (Baumann & Tillman, 2004; Guinée, 2002; Klöpffer & Grahl, 2014). Similarly, LCA experts convey best practices and learn from their own experiences (Baitz et al., 2013; Hauschild et al., 2018; Sonnemann & Margni, 2015). At the same time, the sheer number and diversity of potentially relevant contextual aspects can be bewildering to consider. Hence, uncertainty remains as to how to handle the contextual elements of LCA practices, especially in relation to a perceived necessity for scientifically credible knowledge.

2.4 Balancing scientific credibility and practical utility in LCA

This chapter began by introducing LCA as a science-based method and exploring how LCA developed in the context of sustainable building practices. The existing research has pointed towards an intricate relationship between scientific ambitions and industry-oriented practices in LCA, reflected in concerns about scientific credibility and practical utility (c.f. Baitz et al., 2013 ;Freidberg, 2015; Rex et al., 2020).

Despite sufficient support in the literature for aligning LCA studies with their application context, it remains contested whether contextually adaptive inclinations in LCA are justified in situations where they reduce the scientific credibility of LCA knowledge. Although Ehrenfeld (Ehrenfeld, 1997) argued thirty years ago that LCA can be a useful tool to frame environmental concerns despite apparent limitations as a scientific instrument, there remains today a strong normative support for scientific rigour in the LCA community (c.f. Finkbeiner, 2025; Heijungs, 2024), demarcating 'true' LCA from more contextually adaptive practices.

While scientific inclinations in LCA may guard the credibility of LCA methods, studies, practices, and communities, they may also carry a risk of reducing the usefulness of LCA to decision-makers and other practitioners. The ISO 14040/44 standards do not provide much guidance on these matters, and in this absence, there appears to be a preference in LCA discourse for scientific credibility over adaptations of LCA to the practical context of application. A preference for scientific rigour may come at the expense of the practical usefulness of LCA. To understand and address product environmental impacts effectively, it is therefore worthwhile to focus on what makes LCA work in practice.

3 Philosophical, theoretical, and methodological considerations

The previous chapter introduced LCA and buildings as empirical domains and surveyed the literature on contextual factors in LCA practices. The chapter ended with an observation of a long-lasting tension between scientific credibility and practical utility in LCA practices, and the benefit of researching LCA practices more explicitly. Given the focus on LCA practices in this dissertation, it is important to introduce a few practice-related theoretical considerations.

To support the theoretical positioning of the dissertation, Chapter 3 introduces the philosophical, theoretical, and methodological considerations that frame the research presented. It introduces pragmatism as a (scientific) philosophy that relates the value of knowledge to its practical uses and effects (3.1), discusses substantive and relational strands of practice theory (3.2), and presents methodological lessons drawn from existing research on science and technology studies (STS) (3.3). These different research considerations are tied together (3.4) and present the theoretical context for a subsequent description of the method and research design of the dissertation in Chapter 4.

3.1 Pragmatism

This dissertation explores the potential of making a case for a pragmatic philosophy of LCA. According to pragmatists, the value of knowledge cannot be a factual representation of an independent reality because there are no objective measures outside the human realm to provide an ultimate verification of truthfulness (De Waal, 2021). Instead, pragmatism advocates a purpose-oriented approach, where the value of knowledge lies within the practically conceivable effects it may have on conduct. As the full range of possible effects is practically impossible to comprehend – if only because effects are future oriented and may differ situationally – there remains a degree of uncertainty in knowledge. In doing so, pragmatism avoids a realist–

interpretivist dichotomy where true knowledge is reduced to an accurate representation of an objective reality independent of the observer or to a subjective interpretation of the observer (Ibid.).

Pragmatist lines of inquiry carry consequences for scientific knowledge that addresses the special status it has (been granted) as a true representation of reality. According to Richard Rorty ([1982] 1996), science does not possess a permanent neutral framework that would allow it to have a privileged position to truth reality, given that its own concepts are part and product of that same world. Hence, there is no fixed, a priori, external foundation that could grant this type of neutrality that is conflated with objective rationality. In the absence of a 'mirror-like representation of reality, and given that we can never be absolutely certain, or achieve 'objective' synthesis, the best we can do is to keep the conversation going between different standards or practices of knowledge (Ibid).

Inspired by Peirce, Susan Haack (2003) presents another pragmatist view for addressing the special status of scientific knowledge. While agreeing with Rorty that science does not hold a *privileged* position to a fixed and external true representation of reality, she claims that science instead has gained a *distinguished* position owing to its success in supporting understanding and action about the world. Haack's reason for doing so is that while there may be disagreement on scientific claims within or between communities, there is typically a large degree of agreement on what counts as good scientific evidence or practice. As standards of truth cannot therefore lie entirely within individual scientific practice, there is reason to place trust in science as providing more than what Rorty would allude to as a conversation between ultimately uncertain standards of knowledge. Therefore, according to Haack's pragmatism, there is sufficient reason to value scientific inquiry while maintaining a critical and respectful attitude toward the limitations and uncertainties that scientific knowledge and practice carry (Ibid.).

While both approaches to pragmatism agree on the importance of social interactions and practices for knowledge production, they result in different conclusions concerning the value of scientific knowledge. To Rorty, the inability to escape the confines of our social world implies that there is ultimately nothing beyond language and interactions themselves. As such, the methods of science cannot be a medium to access reality but are to be seen as tools or traditions. While science can be useful in helping people achieve certain goals, interactions among scientists will at best lead to a cultural consensus. In contrast, according to Haack, scientific inquiry has the ambition to represent – i.e. to stand for – the reality it aims to describe (Haack, 2000). Haack argues that scientific inquiry is at least partially shaped by the object of inquiry, implying that a better knowledge of reality could develop in due time, given that sufficient and sincere scientific inquiry takes place.

Despite internal differences, pragmatists agree that the truthfulness of knowledge is at least to some degree relative to the practice of inquiry in which it resides. This aligns a pragmatist philosophy with a Kuhnian perspective that organises scientific practices according to paradigms (c.f. Kuhn, 1967). The question remains whether the value of knowledge is therefore exclusively based on utilitarian grounds in relation to the purpose it serves. For the time being, it is sufficient to acknowledge that pragmatism highlights the limitations of scientific knowledge as providing an unfiltered true representation of reality and supports the importance of recognising the practical effects of knowledge. In doing so, pragmatism leads inquiry away from an analytic high-ground of context-independent knowledge and towards the importance of recognising the particular influences of the scientific and practical contexts in which knowledge is developed and to which it relates.

3.2 Practice theory

The importance attached by pragmatist philosophy to the practical uses and effects of knowledge aligns well with practice theory. Practice theory covers a range of research approaches that take practices as the central unit of analysis. Practices can be defined as arrays of activities based on shared skills or understanding (Nicolini, 2012; Schatzki, 2001). Housebuilding is an example of a practice, as is performing LCA. Practice theory foregrounds the activities that make up practices while setting these in relation to the sociocultural and material aspects that enable and constrain practices. Practices depend on a form of coordination between individual activity and social practice.

Within practice theory, a distinction can be made between practice approaches that predominantly adhere to a substantial and a relational ontology (Gherardi, 2016), reflecting differences of opinion on whether agency is located in social *actors* or in the sociomaterial *relations* that make up practices. Substantive approaches study how the actions of (human) actors are recursively shaped by and shaping the structural contexts in which they take place – institutions, time, space, matter (Giddens, 1984; Shove, 2003). Substantive practice approaches may focus on the direct interaction between knowledgeable actors as well as on the importance of larger structural and material phenomena; they tend to share the recursive relationship between these micro- and macroscale phenomena.

From a substantive perspective, the coordinative dynamic can be explained as a recursive relationship between a specific instance of a practice or praxis (building a house, carrying out an LCA study) and the universal practice itself (housebuilding, doing LCA). The universal practice can be conceptualised as a set of examples, rules and resources on which practitioners draw to carry out a practice in a specific situation. In turn, collective practice is continuously being made and remade as a result of specific instances of practices situated in particular settings. Because specific enactments of practice are not identical – due to agency and the particular setting in which it takes place – these enactments can introduce a dynamic that introduces similarities and differences within practices, leading to changes in shared practices over time and across space. The interaction between agency and structure in social practices is relevant because it drives diversity as well as coherence (Giddens, 1984), avoiding mechanically predetermined behaviour in structuralist or functionalist accounts, as well as anarchic or libertine versions of total individual freedom.

Following a relational ontology, agency is not a property of individual substantive actors but instead emerges from the relations that make up a practice (Schatzki, 2001). This allows researchers to focus on those nets of actors or activities that make a difference (c.f. Czarniawska, 2004; Latour, 2005). At the same time, if agency emerges from continuously evolving relations within actor networks rather than being exercised by stable and tangible (human) actors, it may be difficult to identify who or what is actually making a difference. Latour (2005) therefore suggests empirically tracing the effects that emerge from heterogeneous actor-networks comprising what were previously recognised as independent human actors, technologies, and natural resources. Adopting a flat ontology, relational approaches focus on particular instances of a practice, denying, or at least disregarding, that there is a universal practice from which they draw.

Although intellectually stimulating, a strict relational approach to practice theory quickly becomes challenging in practice. In a relational approach, causal power is no longer exercised by individual social actors in connection to an inert material world. Instead, it emerges from a hybrid mesh of sociomaterial relations, a heterogeneous network in constant flux and without clear boundaries to the outside or within (c.f. Haraway, 1985; Latour, 2005). Although the world and all of its life are in continuous flux, it is clear that within the temporal and spatial boundaries of human action and understanding, people work with categories that are meaningfully stable in everyday practices.

A pragmatic approach suggests that any strict division between substantive and relational approaches may not be especially meaningful in practice. As no single practice approach provides an unfiltered truth of the entirety of practices, it can be useful to combine different practice approaches to develop a richer description of practices in everyday life (Nicolini, 2012). Following a pragmatic approach, it becomes possible to combine the relative stability from substantive practice approaches with the dynamic elements available to relational theories.

On the basis of the literature discussed, a pragmatic perspective of practices may assume that practices are 'carried out' or 'enacted' by human practitioners in a context that is structured sociomaterially, throughout time and space. While the focus may be on the direct interaction between actors carrying out and using LCA, interactions are influenced by forces that are not directly present – i.e. actors belong to networks of agents, practices, technologies, and material resources that shape what actions are possible as well as probable. In turn, specific interactions may recursively shape the networks, practices, technologies, and material resources that comprise them.

3.3 Science and technology studies

To connect these philosophical and theoretical positions, methodological lessons can be learned from scholars of science and technology. Following insights into the relevance of scientific paradigms for organising scientific practices (Kuhn, 1967), researchers in science and technology studies (STS) can be accredited with the methodological innovation of empirically studying the everyday practical work of scientists and engineers (c.f. Knorr-Cetina, 1981; Latour & Woolgar, 1979; Lynch, 1993). By looking carefully at the activities of scientists, including their interactions with machines and nature, these studies show how scientific knowledge, like technology, is not predetermined by nature but rather an outcome of the practices in which scientists and engineers engage within the social and material constraints in a specific situation.

Drawing attention to the detailed inner workings of science and technology, these practice-oriented studies contrasted *natural* determinist views of science, in which scientific results represent solely an objective reality, with scientific activities being reduced to a mirror of an objective reality, or at the very minimum, a neutral filter for removing subjective noise in measurements. Equally, these empirical studies of scientific practice contrasted *social* determinist views that reduce scientific outcomes to a micropolitics of power relations between involved stakeholders (c.f. Bloor, [1976] 1991; Collins & Yearley, 1992) or to the workings of underlying societal power structures. Rather than limiting themselves to fixed *external* explanations for the outcomes of science and technology, whether in society or in nature, STS scholars highlighted the importance of the dynamic *inner-workings* of scientific and technological practices on scientific outcomes, respecting the complex interactions of scientists and other relevant actors with(in) nature, technology, and society.

To generate detailed descriptions of these everyday interactions, qualitative case studies have been carried out on scientific and technological topics ranging from high-energy physics to bicycle use (c.f. Bijker, 1997; Knorr Cetina, 1999). Many have resorted to ethnographic case studies to benefit from empirical detail that can be obtained through direct observations of scientific and technological practices situated in specific settings (e.g. Knorr-Cetina, 1981; Latour & Woolgar, 1979).

In cases where direct observation is impossible or otherwise undesirable, scholars of science and technology have also relied on document- and interview-based studies to reconstruct scientific and technological practices (e.g. Latour, 1996; Pinch & Bijker, 1984; Shapin & Schaffer, 1985). Combining different data collection methods has allowed researchers to access knowledge practices that are spread out spatially and temporally, and to carry out historical analyses of past practices.

3.4 Tying research strands together

Having introduced some key tenets of pragmatism, practice theory, and STS, this chapter concludes by drawing an image of a possible research design that draws inspiration from the interconnected theoretical and methodological contributions made in these fields. Such research would involve a pragmatic understanding that the value of knowledge is shaped by considerations related to its use and effects in real practices rather than being upheld a priori as a scientifically neutral representation of objective reality. A pragmatic approach aligns well with contemporary developments in practice theory that focus on activities and practices as a unit of analysis. It also aligns well with empirically oriented studies of scientific and technological practices carried out in STS. Detailed empirical descriptions of such practices can be produced through an ethnographic commitment to develop multilayered knowledge of scientific and technological practices. Hence, by studying LCA work in practice, it becomes possible to observe the intricate relationships between scientific and contextual inclinations in LCA. These types of studies can be carried out using a mixture of direct observations, interviews, document analyses, and other types of engagements.

4 Method

The considerations from Chapter 3 provided methodological conditions for the study of LCA in practice. By studying LCA work in practice it becomes possible to develop a better understanding of the intricate relationships between scientific credibility and practical utility in LCA and examine the potential for a pragmatic philosophy of LCA. The remainder of this chapter introduces the research design (4.1) and research methods (4.2) that guided the research.

4.1 Research design and trajectory

This dissertation puts forward a thesis on pragmatism for LCA and does so by drawing on the research presented in three papers (Paper I-III). The research has advanced from a longitudinal empirical engagement with building LCA in Sweden, centring on the development of LCA-based practices in four building companies between 2017 and 2025. Initial findings about LCA-based practices in Swedish building companies were presented in the *Licentiate* thesis (Beemsterboer, 2019), marking a half-way point and informing research carried out in the remainder of the PhD.

Between 2017 and 2025, building LCA evolved from being a primarily science-driven practice towards becoming a commonly used method in building companies to address environmental concerns related to the building life cycle. The LCA-based practices examined in Papers I-III reflect an underlying development of these practices in the studied building companies, evolving from a relatively novel to a more routinely used method to understand and address building environmental impacts (see Figure 3). This research strategy supported empirically informed studies of LCA-based practices, as they occurred in the studied building companies during the time of study.

Whereas LCA was novel to most Swedish building companies in 2017, existing LCA practices were aimed primarily at understanding building environmental impacts and how to handle what was perceived to be a complex method. The desire of industry stakeholders to reduce the complexity of building LCA directed the research to focus on simplified LCA in Paper I. As building companies became increasingly familiar with LCA, ambitions grew to use the method for addressing building environmental impacts. Such ambitions in a company led to the initiation of a development project with an explicit LCA-based goal. The study of this project is presented in Paper II, where efforts to understand the substantive effects of LCA were made. Finally, the introduction of legal requirements for LCA-based climate declarations has been key to the rapid expansion of LCA-based activities in building companies. These developments were captured in Paper III.

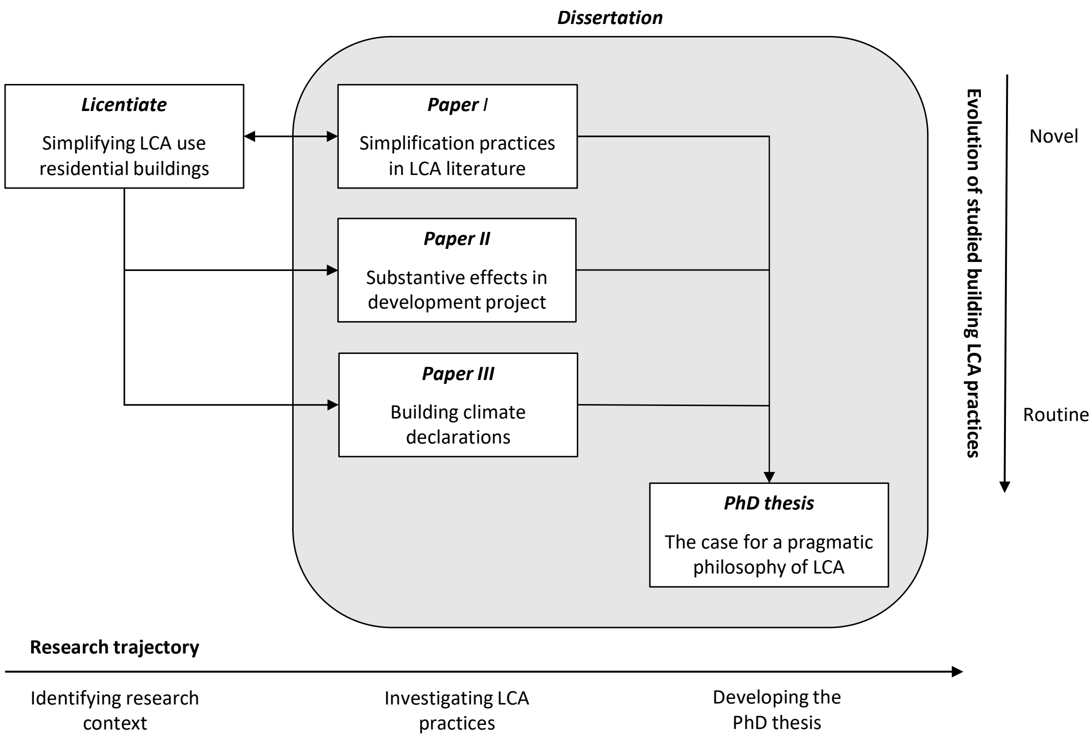

Figure 3: Schematic representation of the research design

Paper I contains a review and systematisation of simplification practices in the LCA literature. The study was conceptualised at a time when the adoption of LCA in Swedish building companies was limited and was perceived to be hindered by the complexity of the methodology (c.f. Beemsterboer, 2019). Paper I intended to support learning processes about LCA in building companies by making insightful a wide spectrum of simplification techniques for carrying out LCA. Expanding beyond a building context, simplifications present a pervasive yet theoretically undervalued of LCA practices. Rather than being a limited version of a ‘full’ LCA, simplification strategies provide a pragmatic solution for balancing completeness and accuracy with practically available resources and intended uses of LCA knowledge. To illustrate the relevance of simplification practices identified in the LCA literature for the studied building companies, the findings of Paper I are complemented with empirical findings from the *Licentiate* thesis.

Paper II contains an ethnographic case study of LCA use in a building product development project carried out by one of the studied building companies. A building product was defined in the project as a standardised building design. The study analysed how LCA use in the development project contributed to a design with a lower climate impact. The research for Paper II was carried out during a period in which building companies were starting to seek ways to use LCA to effectively reduce the environmental impacts of buildings. Product development has traditionally been an important application area for LCA to reduce product environmental impacts (Baumann & Tillman, 2004; McAloone & Pigosso, 2018). Paper II examined whether a linear model of LCA use as informed decision-making provided a valid explanation for the substantive effects of LCA use in a product development project. In doing so, Paper II critically addresses the theoretical and practical dominance of informed decision-making as a concept to explain how LCA may be used to reduce product environmental impacts.

Paper III contains a longitudinal study focused on the evolution of LCA practices in four Swedish building companies between 2017 and 2025. During this period, the Swedish building sector saw the development and implementation of a national regulation mandating that LCA-based climate declarations be carried out in new-build projects. Paper III aimed to examine how LCA practices in building companies developed LCA-based practices in response to the introduction of legislation-driven LCA-based climate declarations with an accompanying methodological standard. This research connects to current developments in the LCA community aiming for policy- or legislation-driven LCA as a means to enforce compliance with environmental goals (c.f. Jegen, 2024; Sala et al., 2021). In addition, Paper III reflects on the popular view that methodological standardisation is a positive and effective instrument for developing a consistent LCA practice.

The research carried out in papers I-III contributed to the development of the PhD thesis, seeking to answer research questions with an empirical, methodological, and theoretical orientation (see *Figure 4*). While the research questions are interconnected, the thesis was developed following a trajectory that was grounded in the empirical domain. Hence, the framing of the research problem followed from the investigation of LCA practices in the context of Swedish building companies between 2017 and 2025.

Hence, in relating the papers to the research questions, Papers I-III successively contribute to a better understanding of the LCA practices studied (RQ1), a deeper understanding of the tension between scientific credibility and practical usefulness in LCA (RQ2), and the potential for a pragmatic philosophy in LCA (RQ3). It is assumed that the studied LCA practices present empirical phenomena worth studying on their own, as well as examples to shed light on the research problem and make a case for a pragmatic philosophy of LCA.

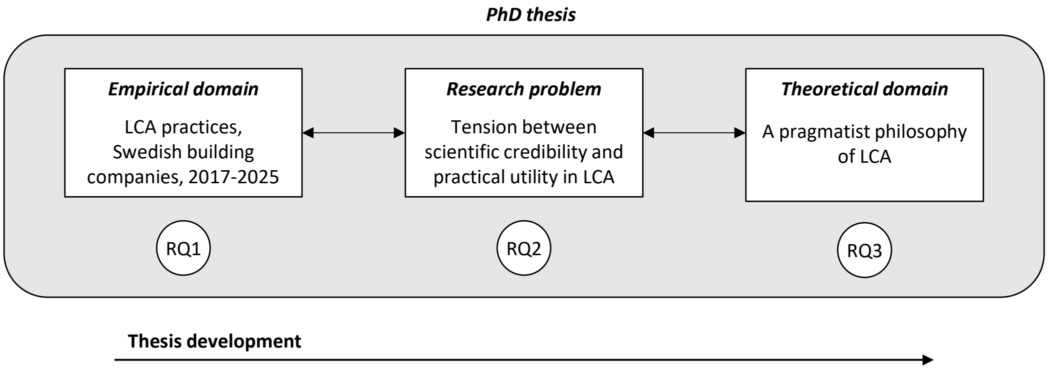

Figure 4: Schematic representation of the thesis development

4.2 Research methods

The remainder of the chapter details the research methods used and the analytical strategy followed. The research conducted as part of this dissertation relies on qualitative methods to empirically study LCA practices (see Table 2).

Paper I is based on a research method that combines a systematic search and review of simplification practices in the LCA literature. The literature search was carried out in Scopus and Web of Science, with a focus on LCA literature that self-identified as simplified, streamlined, scoping or screening. Additional references were added through a snowballing method. A literature sample of 166 articles was generated. The analytic approach targeted the evaluation of new conceptual insights (Grant & Booth, 2009) by carrying out a concept-centric analysis to categorise sets of ideas across articles (c.f. Wolfswinkel, Furtmueller, & Wilderom, 2013). This resulted in a grounded-theory informed generative development of simplifying logics, -strategies, and -techniques on the basis of the simplifications identified in the studied literature.

Paper II is based on an ethnographic case study approach (Atkinson, 2015). The purpose of case selection was to maximise learning opportunities (Stake, 1995). The studied building development project had an explicit LCA-based project goal and was carried out by a Swedish building company with relatively developed LCA competences compared with other companies in the sector at the time. The data were collected in three phases: a pre-study (2016-2017), a development project (2018-2019), and a post-project phase (2021). Data collection was based on first-hand observations (18 days), interviews (32), and project documentation. The analytic process followed an empirically grounded research approach (Alvesson & Sköldberg, 2009; Atkinson, 2015) with a two-step analytical process. A primary analysis of the empirical material was carried out to generate a process-based case description. A secondary analysis was subsequently carried out to identify substantive effects from LCA use and identify deviations from a conventional linear model of LCA use.

Paper III is based on a longitudinal episodic research approach (Pettigrew, 1990) and a nested-case study approach (Yin, 2009). Four building companies and nine building projects were studied between 2017 and 2025. The cases were selected to maximise learning opportunities (Stake, 1995), aligning with an expressed interest from the companies and projects to practice LCA and to participate in the research. Data collection took place in three phases: a few months before the Swedish authorities announced the development of climate declarations (2017), the final year before the legislation entered into force (2021), and nearly three years after climate declarations had become mandatory for new-build projects (2024-25). Data collection was based on interviews (34) and documentation, centring on LCA-based building climate calculations that were carried out in the studied building projects. The analytic process again involved a two-step approach. A primary analysis of the empirical material was carried out to generate a descriptive account of LCA-based practices in the studied building projects and companies. Thereafter, a cross-case analysis was carried out to compare findings from different building companies with each other and answer the research questions.

Table 2: Research methods used in the dissertation

	Method	*Interviews*	*Observations*	*Documents*
Paper I	Literature review			166 articles 163 simplifications
Paper II	Ethnographic case study	32	18 days	5 LCA-based studies Project documents
Paper III	Longitudinal, nested-case studies	34		9 LCA-based studies Project documents

To summarise, the research is based on qualitative research approaches, in the form of a review of simplification practices in the LCA literature (Paper I), and case studies of LCA practices in particular building projects and companies (Papers II and III). In light of the prevalence of quantitative research methods in LCA, it may be useful to briefly explain the qualitative research methods adopted.

Literature review

The literature review carried out for paper I focussed on simplification practices as an empirical phenomenon. While the literature search was systematic, the analysis took a qualitative approach. Owing to the practical impossibility of accessing all possible simplification techniques, the review was limited to the LCA literature that self-identified with simplified or streamlined LCA. Rather than counting the statistical prevalence of particular simplifications across different papers, the analysis took a qualitative approach in the sense of discerning qualitatively different simplification techniques. Following an empirically grounded research approach, this allowed the review to systematise existing simplification practices. Hence, while the literature review contributes a comprehensive overview of simplification practices discussed in the simplification literature, it does not necessarily cover all possible simplification practices that exist in the LCA community.

Case study research

The empirical research that has been carried out in papers II and III has been based on a qualitative case study methodology. Rather than surveying a wide range of LCA practitioners in different contexts about their views and activities regarding LCA (c.f. De Wolf et al., 2017; Jusselme, Rey, & Andersen, 2020; Subal et al., 2024), the empirical research carried out for papers II and III focused on a limited number of companies and projects. Case study research has been carried out before in a sustainable building context (e.g. Georg & Justesen, 2017; Moncaster, 2012) as well as in LCA-based practices (e.g. Nilsson-Lindén, Baumann, Rosén, & Diedrich, 2018; Rex & Baumann, 2007).

The methodological difference between surveys and case studies has implications for the conclusions that can be drawn from the research. Surveys are, in principle, conducted on a sample of a population to draw conclusions that are generalizable to the entire population. Case study research does not intend to provide statistically valid knowledge (Yin, 2009). Instead, case studies can contribute to (1) detailed empirical descriptions of a phenomenon with a high degree of contextual complexity, (2) conclusions about the limits or frontiers of a phenomenon from best or worst cases in a specific contextual setting, assuming that these can be identified, and (3) the development of concepts and conclusions that have a theoretical and practical relevance, and hence, can be used to understand or approach other cases (see also Flyvbjerg, 2006; Ragin & Becker, 1992).

By studying particular companies (paper III) or even a single project (paper II) for an extended period of time, the research prioritised the empirical depth. The research did not intend to produce empirically generalizable conclusions about the current state of building LCA in industry, even if the companies and project selected illustrate what can reasonably be considered relatively successful cases in a Swedish building context. Instead, the empirical research produced detailed descriptions of LCA practices in a Swedish building context. Focusing on specific instances of LCA practices forced respondents and researchers to be specific about the particular activities they carried out. This helped avoid an uncritical reification of what is perceived to be a dominant scientific discourse on LCA. The ambition has been to generate empirically grounded knowledge, with conclusions that have theoretical and practical relevance for comprehending and supporting LCA practices in building as well as other settings.

5 Results of the research papers

Chapter 5 introduces the results of the research papers included in this dissertation. A complete description of these results can be found in the research papers themselves. Paper I focussed on simplification strategies in the LCA literature and will be complemented with findings on building LCA from the licentiate thesis (5.1). Paper II examined the substantive effectiveness of LCA use in a development project of a standardised building design (5.2). Paper III studied the development of LCA-based practices in four Swedish building companies in relation to the introduction of legislation on building climate declarations with an accompanying methodological standard (5.3). Having introduced the results of the individual research papers, Chapter 6 will provide an analysis of the research findings to answer the research questions raised in this thesis.

5.1 Paper I: Simplification practices in the LCA literature

Paper I reviewed and systematised simplification practices in the LCA literature (Beemsterboer, Baumann, & Wallbaum, 2020). Simplifications are pervasive in LCA practices and connect directly to the purpose and available means to carry out LCA studies. Nonetheless, despite the key role of simplifications in producing useful LCA knowledge, there is a constrained and fragmented discourse on the topic.

The results of Paper I present evidence of a rich and diverse palette of simplification techniques available to LCA practitioners. The findings were systematised according to simplifying logics, simplification strategies, and operational simplification techniques (see Table 3). The findings support the existence of five overarching simplifying logics: (1) exclusion, (2) inventory data substitution, (3) qualitative expert judgment, (4) standardisation and (5) automation. Together, these simplifying logics support 13 different simplification strategies.

Table 3: Three levels of simplifications illustrated with the exclusion simplifying logic

Levels of simplifications	*Example for the exclusion simplification logic*
Simplifying logic	Exclusion
└ Simplification strategy	└ Exclusions in the inventory model
└ Simplification technique	└ Exclusion of upstream energy sources

Source: Beemsterboer et al, 2020.

The identified simplification approaches allow LCA analysts to balance a comprehensive mapping of complex product systems with available resources and the expectations of users related to the goal and timing of an LCA study. Simplification practices have remained a relevant part of LCA because the challenges related to balancing product complexity, available resources, goals, and timing have not disappeared since the streamlining debate of 1990. Even if technical advances in LCA regarding methods, guidelines, software, and databases have made it easier and faster to carry out LCA, they have not and cannot eliminate the contextual setting in which LCA is practised.

Findings from the Licentiate thesis

The 13 identified simplification strategies resonate with methodological developments in building LCA research as well as the studied building companies. For example, it is customary practice to exclude building elements, life cycle stages, and impact categories. Similarly, building companies relied relatively heavily on building specific LCA software with accompanying datasets with average emission data for generic construction materials (c.f. Beemsterboer, 2019), with EPD-based results being used as sources of primary data.

Simplified LCA practices have an instrumental purpose of allowing building companies to learn about LCA and learn to understand which building elements and building materials potentially contributed the most to global warming. From the perspective of the building companies, upstream climate calculations became a way to expand environmental concerns to include embodied carbon impacts related to the product stage (A1-3). In this context, it is relevant to recognise that operational energy use (B6) was already addressed in the building companies by instruments other than LCA. With time, as building companies learned to understand and address the potential climate impacts associated with the product stage, LCA practices could expand the scope to include construction processes (A4-5). Next steps may include a full building life cycle assessment (A-C) as well as other environmental impact categories.

Second, in addition to a learning perspective, there are particular contextual factors in building that shape how LCA is practised. Buildings are resource intensive, composite products with long service lifetimes. In addition, buildings are typically planned, designed, and constructed in individual building projects connected to a specific building site and market. These aspects not only contribute to the complexity of building LCAs but also lead to a planned practice of specific LCA studies within building projects. Under these conditions, it is necessary for building LCA companies to be efficient when carrying out LCAs.

While growing LCA competence and technical developments may support a gradual expansion of LCA practices, it remains important to recognise that the contextual aspects that lead practitioners to simplify are not the only ones that affect how LCA is practised within a building setting.

5.2 Paper II: Substantive effectiveness of LCA use in a development project

Paper II contains an ethnographic case study of LCA use in what was termed a building product development project carried out by one of the studied building companies (Beemsterboer, Baumann, & Wallbaum, 2025). The paper examined whether a linear model of LCA use as informed decision-making provided a valid explanation of the substantive effects of LCA use in the development project. Substantive effectiveness was demonstrated when LCA use led to environmentally beneficial changes in a product system. It differs from accurate or efficient LCA applications, which do not necessarily reduce the environmental burdens of a product system.

The linear model represents a rational and knowledge-driven understanding of LCA use by assuming that the results of a commissioned LCA study inform a decision that improves the environmental performance of a product system (see Figure 5). Following a linear model, it is common notion that the effectiveness of LCA can be improved by producing better environmental information more efficiently or by improving the communication of LCA results to the decision maker.

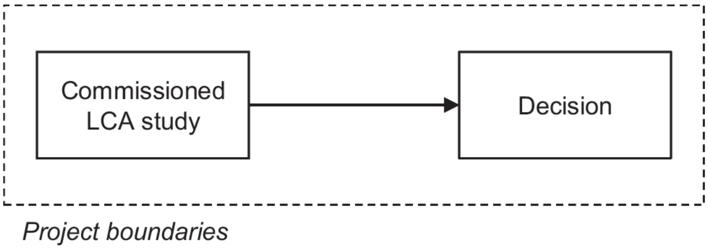

Figure 5: A schematic depiction of the conventional linear model of LCA use (Beemsterboer et al., 2025).

Contrary to popular perceptions, the findings of Paper II revealed that substantive effects from LCA use are varied in nature and cannot be reduced to a conventional linear model. The studied development project created a building design with 8–14% lower expected GWP emissions compared to an internal reference product. Rather than being limited to a single decision, LCA practices led to substantive effects following a complicated sequence of events that connected products, practices, people, and organisations.

Paper II identified six mechanisms that led to effects and that deviated from the linear model of LCA use as informed decision-making: (1) multiplicity, (2) partial effects, (3) displaced effects, (4) activity-based effects, (5) heterogeneous actors and activities, and (6) a two-way directionality of effects. Compared with the conventional linear model of rationally informed decision-making, the identified effect mechanisms explain more complex cause–effect paths in relation to LCA use.

While relying on a conventional linear model may enable LCA practitioners to focus on producing scientifically credible information, it disregards whether a linear knowledge-based LCA practice is the most effective way to reduce product environmental impacts. To support LCA researchers and practitioners with alternatives to the linear model of LCA use, three alternative knowledge- and activity-based models have been proposed (see Figure 6).

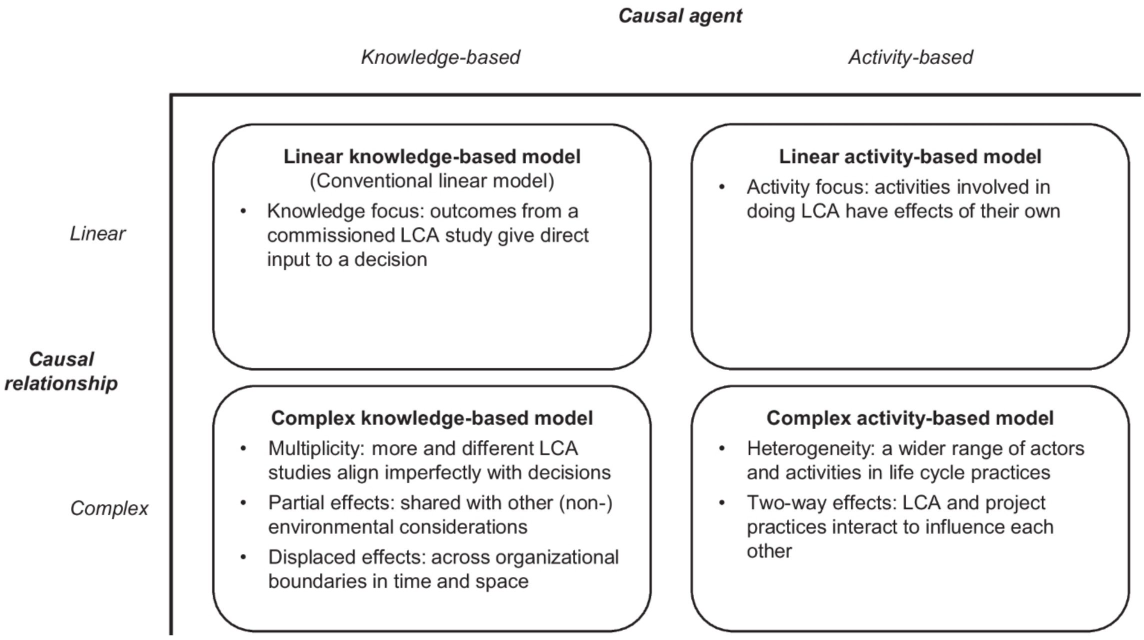

Figure 6: Four models of LCA use based on different effect mechanisms (Beemsterboer et al., 2025)

5.3 Paper III: Climate declarations and the development of LCA-based practices

Paper III contains a longitudinal study focused on the development of LCA practices in four Swedish building companies between 2017 and 2025. During this period, the Swedish building sector saw the development and implementation of a national regulation mandating that LCA-based climate declarations be carried out in new-build projects. Paper III examined LCA practices in building companies before and after the introduction of LCA-based climate declarations and its accompanying methodological standard.

By introducing a legislation-driven LCA application, such as building climate declarations, governing authorities require organisations to carry out assessments that are compliant with the methodological standard that accompanies the legal requirement. Methodological standards have a long history in supporting scientific credibility in the LCA community. Given that the accurate representation of environmental loads and impacts connected to a product life cycle cannot be proven by comparison to a real concrete object, LCA researchers and practitioners have learned to rely on methodological standards to reduce the space for subjective choice, creating what is termed 'mechanical objectivity' (c.f. Lazarevic & Martin, 2018; Porter, 1995).

Paper III revealed a remarkable increase in the volume and variety of LCA-based activities in the studied building companies between 2017 and 2025. Identified LCA-based practices connected to (1) procurement, (2) design optimisation, (3) climate declarations, (4) research and development, (5) environmental certification schemes, (6) purchasing and sales, and (7) company strategies. Where the anticipation and introduction of legal requirements were instrumental in creating a demand for LCA, building companies did not rely formally on climate declarations to address building environmental impacts.

Paper III revealed practical reasons for not limiting LCA-based practices to a shared methodological standard. By resisting the pressure to follow a shared methodological standard, the studied companies practised LCA in ways that better aligned with the goals, opportunities and constraints present in building projects and other application contexts. Despite being legally obliged to conform to a methodological standard for LCA-based climate declarations, the building companies developed parallel LCA-based practices that aligned with the different purposes, contextual factors, and institutional logics present in building projects and other organisational settings.

6 Analysis

Having introduced the results of the individual research papers, Chapter 6 continues with an analysis of the research findings aimed at answering the research questions addressed in this thesis. As described in the research design (4.1), the PhD thesis followed an empirically grounded research approach, starting from particular LCA practices and the four studied building companies (6.1, RQ1). The evidence gathered was used to draw conclusions on the challenge of balancing scientific credibility and practical utility in LCA (6.2, RQ2) and subsequently examine the potential for a pragmatic philosophy in LCA (6.3, RQ3).

6.1 LCA practices in four Swedish building companies

As a central part of the empirical research, Papers II and III included findings that help understand how LCA practices work in Swedish building companies (RQ1). Both the volume and variety of LCA practices in the studied building companies increased dramatically during the period of 2017-2025. Whereas in 2017, only one company systematically carried out LCA-based climate calculations, by 2025, all four studied companies had developed multiple LCA-based practices.

The studied building LCA practices adopted a relatively narrow scope in comparison to the full range of life cycle stages and the impact assessment categories available to LCA. With respect to the scope, the studied building LCAs fall short of the scientific ambitions presented in ISO14040/44 to present a 'comprehensive' assessment of life cycle stages and environmental impacts. Initially, the relatively limited scope of the building LCA practices was perceived to be related to the novelty of the method in the studied building companies and subsequent limitations in data and expertise (Beemsterboer, 2019).

In 2017, it was not unusual for inexperienced companies to limit LCA-based climate calculations to the product stage (A1-3). Data collection was perceived to be a time-consuming process. When and where companies and analysts were becoming more acquainted with the method, and data collection processes had improved, LCA practices were seen to gradually expand the scope by including more life cycle stages. By 2025, building climate calculation for the product and construction stages (A1-5) was a widespread practice among the studied building companies and was mandated by the Swedish authorities. In addition, on a few occasions building companies had started expanding the scope and level of detail in LCA-based climate calculations, by considering technical systems, as well as parts of the use stage (B) and end of life stage (C) (Paper III).

With respect to the environmental impact categories assessed, the studied building LCA practices focused nearly exclusively on GWP. Although a singular focus on GWP has never been a question of concern in the studied building LCA practices, it contrasts with comprehensive ambitions in the LCA community that are intended to avoid burden shifting between different environmental aspects if it leads to sub-optimal outcomes. While data availability plays a role, it cannot in itself explain the consistent ignorance of other environmental aspects in building LCA practices. Although publicly available LCI databases from Boverket and IVL are limited to GWP, there are also EPD data and proprietary LCA databases containing a larger subset of environmental impact categories. Hence, it appears that institutional aspects also play a role in the relatively modest scope of building LCA practices.

In addition to a relatively modest scope, the research findings showed that the studied building LCA practices were commonly adjusted to fit the application and use context in which they were situated. Local context mattered in the studied building LCA practices because of the importance of the building site as well as project-based organising. The degree of integration of LCA in building projects has developed over time and across building companies. In 2017, LCA was mainly restricted to research and development settings, even if one company had started to systematically assess building designs produced in projects. By 2025, all the studied building companies showed evidence of carrying out LCA-based climate calculations as an integral part of building projects, and all the studied building projects were able to show improved building climate performance (Paper III).

Paper II showed that LCA use may influence building environmental performance following a complex sequence of events rather than being reduced to a rational and linear notion of informed decision-making. The limited validity of the linear model of effect on the development project studied in Paper II was also evident in the LCA-based practices studied in Paper III. Here, the process of framing environmental concerns in building projects, including relations with clients and suppliers, was perceived to be an important source of influence for LCA. Although commissioned LCA-based climate calculations were frequently used to confirm whether environmental targets or goals were met, the outcomes of these studies rarely guided improvements in the environmental performance of the building designs.

While the different case studies showed a degree of coherence between the studied building LCA practices, coherence should not be confused with conformity to a shared methodological standard. First, it may appear that inconsistent LCA practices could be explained by the presence of different methodological standards – e.g. ISO 14040/44, EN15978, the Swedish regulation on building climate declarations, and environmental certification schemes. However, the empirical studies presented in papers II and III showed that LCA practices also deviated from the methodological standards themselves. These inconsistencies tended to emerge through the interaction between building LCA practices and other (sustainable) building practices in projects and companies. Notably, the studies showed that the inconsistencies resulting from interactions with building practices frequently coincided with reduced building environmental impacts.

The importance of interaction for addressing building environmental impacts suggests that it is desirable for LCA to be integrated into building practices, building companies, and building projects. The research presented in this dissertation provides evidence that integrating LCA in building projects has repercussions for how LCA is carried out. In building projects, it is not merely the analyst who, inspired by methodological standards and available resources, has the discretionary power to determine how LCA is to be carried out. Instead, LCA studies are carried out by the LCA analyst in interaction with project managers, structural engineers, clients, and other relevant actors. The outcomes of these interactions are not predetermined and can be influenced by a range of factors and concerns that belong to the application context.

Hence, rather than presenting a single and somewhat simplified form of LCA, the research took notice of a variety of LCA-based practices that aligned with different building practices. Paper III showed how LCA-based practices were connected to (1) procurement, (2) design optimisation, (3) climate declarations, (4) research and development, (5) environmental certification schemes, (6) purchasing and sales, and (7) company strategies. In addition, Paper II described the use of LCA in a product development project of a standardised building design.

The empirical and analytical findings do not present an exhaustive overview of all existing building LCA practices. Nonetheless, the findings show how a science-based understanding of LCA is of limited use to understand how the method works in sustainable building practices. Rather than advocating scientific rigour through comprehensive knowledge, rationality, and consistent use of methodological standards, the research findings revealed how the studied LCA practices were adjusted to be practically useful in the company and project settings in which they were situated.

6.2 The tension between scientific credibility and practical utility in LCA

On the basis of these empirical findings, conclusions can be drawn regarding the challenge of balancing scientific credibility and practical usefulness in LCA (RQ2). The research provided three strands of evidence that underscore the limitations of viewing LCA primarily as a method for producing scientifically credible knowledge about potential product environmental impacts. The simplification strategies that were reviewed in Paper I could be framed in relation to scientific ideals of complete and accurate LCA knowledge. Paper II showed how a rational and linear model of informed decision-making failed to account for the complex sequence of events and different mechanisms by which substantive effectiveness was achieved in a product development project. Paper III highlighted the variety of LCA-based practices that have developed in the studied building companies, deviating from a legally enforced methodological standard, and existing side-by-side to fulfil different purposes for the involved stakeholders.

Rather than aiming for complete and accurate representations of product environmental impact, LCA practices continue to build on simplification strategies to perform useful work (Paper I). Simplifications are frequently associated with a limited form of LCA and with incomplete and inaccurate representations of environmental loads and impacts. Consequently, simplifications often remain invisible in the final results. Even if scientific credibility requires transparency, it may be difficult to be open about simplifications in LCA as they are also associated with a lack of expertise as well as incomplete knowledge. At the same time, the pervasiveness of simplifications in LCA illustrates that practical utility cannot be discounted. Simplification strategies are a way for LCA to align with practical concerns about analytical resources such as time, money, data, and competence, as well as the purpose and context of application. In particular, they are exemplary for understanding that it is not always effective to aim for a complete representation of product environmental impacts.

Paper II further highlighted limitations of scientific credibility as a guiding mechanism in LCA. The case study showed how improvements in building environmental performance did not follow the outcomes of commissioned LCA studies but resulted from interactions that took place within the project. In addition, where LCA results influenced the development project, this could be attributed mainly to LCA studies commissioned elsewhere on different buildings. In contrast to basing decisions on a linear model of informed decision-making, LCA contributed to substantive effects in the studied development project through a complex sequence of events following a spectrum of knowledge- and activity-based mechanisms. In doing so, Paper II showed the limitations of the rational and linear model of informed decision-making in explaining how LCA use may reduce product environmental impacts.

In Paper III, the relation between a regulatory methodological standard and the development of LCA practices was examined. While the studied building companies are legally obliged to conform to a methodological standard for LCA-based climate declarations, they nonetheless developed parallel LCA-based practices that fitted with different purposes for LCA use in building projects as well as other organisational settings. Notably, deviations from the methodological standard were especially visible in areas where LCA was actively integrated into the building project to reduce building environmental impacts. Rather than restricting themselves to the methodological standard, LCA practitioners continued to align their building climate calculations also with the logics and purposes of other project actors, such as project managers and clients. In doing so, the LCA practitioners were able to safeguard the practical utility of their climate calculations while also complying with the legal requirements.

Although concerns for scientific credibility are a central part of the academic LCA discourse, they were less relevant for understanding the studied LCA practices. Instead, the research findings showed how considerations of practical utility were adopted to make LCA meaningful and useful to the actors involved. Key practical and contextual considerations included (1) the availability of assessment resources, such as, time, data, expertise, and money, (2) practical purposes and uses, and (3) interaction with relevant actors in the context of application.

While strong normative support for guarding the scientific credibility of LCA may be understandable given the great difficulty in ascertaining whether LCA results are true expressions of product environmental impacts, the research findings suggest that uncritical support for scientific credibility may provide disservice to LCA practices if it limits the usefulness and practical effects of LCA. Currently, concerns of practical utility are perceived to be hindered by the dominance of a science-based discourse in the LCA community, leading to an uneven discourse on the topic. To arrive at a more balanced perspective, it would therefore be useful to develop an epistemic counterweight that supports concerns of practical utility in LCA.

6.3 Towards a pragmatic philosophy of LCA

The research findings showed how the studied LCA practices involved a range of practical and contextual considerations related to the practical utility of LCA. To become better attuned to such practical issues, it would be beneficial to consider the potential merits of pragmatic philosophy of LCA (RQ3).

Section 6.2 expressed that considerations of analytical resources, purposes and uses, and interactions in the application contexts are relevant to understand the practical utility of LCA, making them relevant for a pragmatic philosophy. Currently, the goal definition and interpretation phases provide space to acknowledge the importance of purpose and context. Compared with the detailed attention given in the ISO standard and the LCA literature to procedures that improve scientific rigour of LCA, there is a limited and fragmented discourse recognising the centrality of practical purposes and contextual conditions in LCA practices. Consequently, the vocabulary, theories, and methods in LCA are underdeveloped with respect to supporting researchers and practitioners in considering the importance of practical utility and effects in LCA.

The tenets of a pragmatic philosophy for LCA are not set in stone. However, it is clear that valuing practical utility involves an understanding and appreciation that (1) practical issues and settings play a role in shaping LCA – i.e. LCA practices, studies, results, data, methods, standards, and so on – and (2) the value of LCA is connected to its usefulness and practical effects in the application and use contexts.

Notably, pragmatist thinking involves more pronounced and more moderate approaches to address practical considerations in relation to the possibility of scientific truth. In a more pronounced version, Rorty ([1982] 1996) finds that the value of knowledge results from what works in a practical context. In the absence of a single or objective standard for evaluating the truthfulness of knowledge, Rorty's version of pragmatism leaves little space for fixed measures supporting scientific credibility. In contrast, Haack (2003) presents a more moderate philosophy where even if science may not produce truth, it can still be distinguished from other forms of knowledge owing to its successes in understanding and addressing the world.

In this context, a preference for a more pronounced or moderate pragmatist philosophy could be left open to the purpose that it is expected to serve in LCA discourse and practices. In situations where LCA researchers and practitioners are susceptible to pragmatist considerations, a moderate pragmatist approach may be sufficient to balance scientific credibility and usefulness. In contexts with staunch science-driven LCA practices, it may be necessary to develop a more pronounced pragmatic counterweight, in the hope that this may support a more balanced practice.

At times, the studied building LCA practices and the academic LCA discourse have appeared as two worlds that exist independently from each other. In the final words of this chapter, I would like to stress the connections between these two spheres of LCA. While highlighting limitations of scientific credibility as a guiding principle for LCA practices, it remains necessary to understand that LCA practices also need to be credible for them to be useful. This suggests that a moderate pragmatist approach may be most useful for balancing scientific credibility and practical utility in LCA.

7 Discussion and conclusions

This dissertation provides evidence of a variety of LCA-based practices across and within a complex of contextual settings. Empirically, the research was grounded in the context of building LCA practices, especially in those practices that existed in the studied building companies in Sweden between 2017 and 2025. Furthermore, the individual papers have addressed particular aspects of LCA practices with relevance outside a building context – i.e. simplifications, substantive effectiveness and decision-making, and methodological standardisation.

In the previous chapter it was asserted that a discourse around scientific credibility is insufficient to explain how LCA works in sustainable building practices. The analysis revealed that the issues promoted by a concern for scientific credibility – e.g. comprehensiveness, informed decision-making, and methodological standardisation – failed to explain many of the activities that were present in the studied LCA practices. Rather than focussing on scientific credibility, the studied LCA practices presented strong concerns for practical utility. LCA practitioners contributed pragmatically to an understanding and addressing of product environmental impacts by aligning LCA with available analytical resources, purposes and uses, as well as interactions with relevant actors in the application and use contexts. In support of a more explicit consideration of these practical concerns, a case was made for a pragmatic philosophy of LCA.

Following the empirical and analytical findings, Chapter 7 continues with a discussion of the research outcomes. The chapter starts with a reflection on limitations of the conducted research (7.1). Thereafter, the contributions of the research outcomes are discussed (7.2), including the implications of the main conclusions (7.3). The chapter ends by pointing to avenues for further research (7.4).

7.1 Reflections on research limitations

Studying particular building LCA practices using a qualitative research approach has implications for the way that the research was carried out as well as the generalizability of the empirical findings. Rather than working with a predefined theoretical definition of these concepts, the research followed an empirically grounded approach in which scientific credibility and practical utility were given meaning in relation to the studied LCA and building practices. Scientific credibility was related to a scientific rigour, comprehensiveness, consistency, transparency, standardisation, rationality, and informed-decision making. Practical utility was related to available analytical resources to practice LCA, practical purposes and uses, and interaction with other actors in the context of application. While both concepts have been addressed in this dissertation, it remains important to emphasise that their meaning is at least partially contingent on the LCA and building practices studied, and therefore, does not provide an exhaustive or definite account of either concept.

The empirical context turned out to be supportive for understanding the limitations of scientific credibility as a guiding mechanism in LCA. By studying building LCA practices, the dissertation focussed on a domain with a high volume of LCA and LCA-based studies, owing in part to a dominant practice of designing and constructing buildings in individual building projects. The resulting tendency for individual building LCAs was strengthened by the introduction of LCA-based climate declarations in the Swedish context. The high volume of building LCAs and the local organisation of building projects make it likely that the studied building context was more inclined to embrace pragmatic values than, for example, a centrally organised industry with mass-produced products.

Nonetheless, while the research findings cannot be uncritically applied to any contextual setting, it is worth recognising that the core concerns addressed in this thesis have a relevance that stretches beyond the building context studied. For example, the understanding that LCA results may vary widely between studies of similar products is shared between building (Moncaster, Pomponi, Symons, & Guthrie, 2018; Rasmussen et al., 2018) and other product domains (e.g. Bjørn et al., 2018; Ekvall, 1999), raising a shared concern for scientific credibility. Similarly, a recognition of contextual influences has inspired industry-based studies on LCA practices in building (Moncaster et al., 2023) and other sectors (e.g. Baumann, 1998; Frankl & Rubik, 2000; Rex & Baumann, 2007; Niero et al., 2021; Tessitore et al., 2025; Testa et al., 2017). Although LCA practices have become specialised along sectoral lines, concerns of scientific credibility and practical utility are evidently relevant to different product domains and practices.

Given the presumed richness of empirical phenomena, qualitative research approaches are not intended to provide definitive accounts of the practices studied (c.f. Alvesson & Sköldberg, 2009; Atkinson, 2015). This dissertation does not arrive at any final conclusions of how LCA is or ought to be practised in the building domain, or how scientific credibility and practical usefulness are given meaning across the LCA community. Instead, the research produced empirically informed accounts of particular LCA practices, intending to shed light on methodological issues that have relevance beyond the specific context that was studied.

With respect to the generalisability of the research findings, it should be pointed out that the particular LCA practices, building projects and companies studied in this dissertation are not representative of building LCA practices as a whole. Similarly, building LCA practices are not representative of practices in the entire LCA community. Nonetheless, this does not imply that the contributions made in this dissertation cannot be used to inform and understand LCA practices in other settings.

7.2 Contributions of the dissertation

The contributions of this dissertation can be subdivided into those that belong to the PhD thesis and those that belong to the individual research papers. This section starts with a discussion of the contributions of the thesis, describing how the analyses presented in Chapter 6 relate to existing research on building LCA practices, the tension between scientific credibility and practical utility, and pragmatism in LCA (RQ1-3). Thereafter, this section will briefly discuss the contributions of the individual research papers on simplification practices, substantive effectiveness in LCA, and the role of legislation-driven LCA standards (Papers I-III).

LCA works in sustainable building practices because it is adjusted to be practically useful

This dissertation has contributed empirical evidence to show how LCA works in sustainable building practices by accommodating different considerations of practical utility, even in situations where this contradicts a common concern for scientific credibility in LCA. Rather than being an expression of undue subjectivity or inaptitude, the research provided evidence of legitimate LCA-based practices that serve to adjust a relatively standardised LCA methodology to specific purposes and social and material contexts in practical settings.

The empirical research focused heavily on industry-based building LCA practices, contrasting and complementing a focus on understanding building environmental impacts in building LCA research (e.g. Birgisdottir et al., 2017; Birgisdottir & Stranddorf, 2023). Despite a shared interest in buildings as the object of assessment, industry-based building LCA practices have been shown not to necessarily share the science-driven ambitions present in the building LCA research community (e.g. Lützkendorf & Balouktsi, 2023). Hence, rather than committing to a science-based agenda for developing LCA practices in the building industry, the research presented in this dissertation contributes to an industry-based understanding of LCA practices.

Currently, the understanding of industry-based building LCA practices is frequently derived from survey studies (e.g. Balouktsi et al., 2020; Jusselme et al., 2020), limiting analytical depth in favour of a larger sample size of practitioners in a given population. Despite recognising the complexity of industry-based applications, recommendations for developing industry-based building LCA practices have frequently been reduced to data availability, methodological standardisation, and formal targets or regulations (e.g. De Wolf et al., 2017; Passer et al., 2023). By carrying out qualitative case studies of LCA practices, this research developed descriptions that contribute to novel insights on how LCA is practised in the building companies (see sections 5.2, 5.3, and 6.1).

To my knowledge, there are only a few empirically informed case studies examining LCA practices in the building industry (c.f. Moncaster et al., 2023). Case studies of industry-based LCA practices are relevant because they allow empirical descriptions and analysis on the basis of how building LCA is actually practised in industry, rather than how it ought to be practised according to LCA researchers. Notably, the findings in this dissertation have made clear that industry-based experiences do not always correspond to the predominantly scientific concerns of LCA researchers. Recognising the importance of the empirical context for LCA practices is consistent with findings in other industry-based settings (c.f. Baumann, 1998; Lazarevic & Martin, 2018; Niero et al.; Nilsson-Lindén, Diedrich, & Baumann, 2021; Rex et al., 2020; Testa et al., 2022).

Although both science-driven and industry-driven LCA practices contribute insights into building environmental performance and potential design improvements, a more pronounced focus on industry-driven LCA practices helps understand how, when, and where tangible changes in building environmental performance can be realised.

Concerns of practical utility are at the heart of LCA

This dissertation explicitly identifies concerns of practical utility and context to be central to LCA practices themselves – irrespective of any boundary that may be drawn between the inner workings of LCA and the outer settings in which it is applied. Key practical and contextual considerations are (1) the availability of assessment resources, such as, time, data, expertise, and money, (2) practical purposes and uses, and (3) interaction with relevant actors in the context of application.

The findings in this thesis support a deeper understanding of the importance of balancing scientific credibility with practical utility in LCA applications (c.f. Baitz et al., 2013; Freidberg, 2015; Rex et al., 2020), relating to simplification strategies, rational ideas of informed decision-making, and methodological standardisation. The LCA community has long been aware of the limits of a scientific concern for objectivity or factual knowledge to explain what LCA contributes with, recognising the intricate relation to social, subjective, cultural, and practical elements that pervade the method and practice (Allenby, 1998; Ehrenfeld, 1997; Hertwich et al., 2000; Tukker, 2000).

The nuances of what contextual elements are considered to belong to what parts of LCA differ greatly and range from strong support for scientifically and mathematically rigorous knowledge (e.g. Finkbeiner et al., 2025; Heijungs, 2024) towards positions that emphasise normative and social concerns (e.g. Boons & Howard-Grenville, 2009). In the context of rhetorical cross-fire, it is easy to lose the sense of nuance and relapse into dichotomous positions that contrast scientifically objective LCA knowledge against subjective contextual influences.

Hence, it is perhaps not surprising that LCA continues to be demarcated as a science-driven practice, even in situations where contextual elements are clearly shown to matter (e.g. Lützkendorf & Balouktsi, 2023; Sonnemann & Margni, 2015). Practical considerations regarding purpose and application context have been recognised in the ISO standards (ISO, 2006a, 2006b) as well as popular textbooks in LCA (Baumann & Tillman, 2004; Guinée, 2002; Hauschild et al., 2018). Hence, there is support within the mainstream LCA discourse for acknowledging practical utility in LCA. However, at the same time, it has not been uncommon to restrict these concerns to an application context lying outside of the 'inner workings of LCA' as part of decision-making, life cycle thinking (LCT) or life cycle management (LCM) (e.g. Hauschild et al., 2018; Sonnemann et al., 2015).

The findings in this dissertation will not resolve the tension between scientific credibility and practical utility in LCA. However, the findings will hopefully contribute to a better understanding of the depth with which concerns of practical utility and context are part of LCA. In doing so, the research findings implicitly support a more contextual understanding where LCA methods and practices are adjusted or translated to align with the practices in which they are situated (c.f. Heiskanen, 2002; Nilsson-Lindén et al., 2019; Testa et al., 2022).

The case for a pragmatic philosophy of LCA

The research findings presented in this dissertation were used to make a case for a pragmatic philosophy of LCA. A pragmatic philosophy of LCA embraces considerations of practical utility in how LCA is practised, claiming that the value of LCA lies in the purposes it serves and the conceivable effects it has on other practices, such as sustainable building. By making a case for a pragmatic philosophy of LCA, this thesis contributes to a more explicit concern for practical considerations in LCA discourse and practice.

Previously, pragmatist thinking in LCA was connected mainly to a colloquial use of the term pragmatic, typically in support of the practical application of LCA. Along these lines, authors have related pragmatic aspirations to efficient applications of LCA (Auer, Bey, & Schäfer, 2017; Six et al., 2017), more effective communication (Salemdeeb et al., 2021), and decision making (Buytaert et al., 2011). A pragmatic solution has been framed as belonging to a scientific discourse where novel standards, methods and tools are expected to improve LCA practices (e.g. Guinée et al., 2004; Laurent et al., 2020; Valdivia et al., 2021). Compared with these colloquial expressions of pragmatist thinking, Schaubroeck (2023) presented a relatively integrated approach by identifying three pragmatic criteria for LCA application – i.e. ease of application, practical value in relation to decision support, and consideration in standards (sic!). In relation to the literature, this dissertation contributes what can be regarded as an empirically informed justification for a pragmatist philosophy in LCA.

Other contributions to the field of LCA

In addition to discussing the relevance of practical utility for LCA, the dissertation also includes three research papers with individual contributions to the LCA community – i.e. simplification practices (Paper I), the substantive effectiveness of LCA use (Paper II), and the role of regulatory methodological standards in industry-based LCA practices (Paper III). In the remainder of this section, the contributions of the individual papers are briefly discussed.

Paper I presented the first systematisation of simplification practices in the LCA literature since the streamlined LCA discussion of the 1990s (c.f. Christiansen, 1997; Graedel, 1998; Todd & Curran, 1999; Weitz, Todd, Curran, & Malkin, 1996). While other studies have proposed novel simplification techniques (e.g. Olivetti, Patanavanich, & Kirchain, 2013) and surveyed the application of simplification techniques for a specific product system (e.g. Soust-Verdaguer, Llatas, & García-Martínez, 2016), there were no reviews available that reviewed the entire scope of the LCA simplification literature. Although novel at the time of publication, the discussion on simplification techniques in the LCA literature has since been enriched with another review (Gradin & Björklund, 2021).

The findings in Paper I complemented existing research by providing a comprehensive overview of simplification techniques available in the LCA simplification literature until 2019. The wide spectrum of potential simplifications in LCA has been made insightful by organising them in a three-level hierarchic system, following (1) simplifying logics, (2) simplification strategies, and (3) simplification techniques. The results have added a vocabulary and systematisation that allows a better understanding of the variety of available simplification techniques on the basis of shared simplifying logics and strategies. The systematisation of simplifications according to their internal logic juxtaposes a mapping of simplification approaches by LCA phase (c.f. Gradin & Björklund, 2021).

Paper I added standardisation and automation as simplifying logics that were absent from the original streamlining debate. By reducing methodological choices, data, and calculation work, simplifications such as standardisation and automation introduce process-oriented improvements that enable practitioners to handle more complexity in LCA. By enabling more LCA work to be done with a given amount of analytical resources, process-oriented simplifications have the potential to increase the completeness and accuracy of LCA studies. These findings provide a useful contrast to model-based simplifications such as exclusion or inventory data substitution, which are discussed as potential sources of inaccuracies in LCA (c.f. Lasvaux, Schiopu, Habert, Chevalier, & Peuportier, 2014; Rasmussen et al., 2018).

Paper II presented an ethnographic case study of LCA use in a building product development project to better understand the substantive effectiveness of LCA use, examining whether a linear model of LCA use as informed decision-making could actually explain the tangible effects of LCA use in this practical setting. The findings in this paper shed new light on the role of LCA in a decision context (Hertwich et al., 2000; Pryshlakivsky & Searcy, 2021; Subal et al., 2024) by confirming the importance of recognising the complexity and contextual relevance of real decision-making processes (Blass & Corbett, 2018; Boons & Howard-Grenville, 2009; Niero et al., 2021; Tukker, 2000; Vermeulen, 2006).

Despite widespread agreement on the importance of understanding LCA practices in relation to their empirical setting, relatively few studies have made empirically informed contributions to this topic (e.g. Baumann, 1998; Freidberg, 2015; Lazarevic & Martin, 2018; Rex et al., 2020; , Tessitore et al., 2025; Testa et al., 2022). While other authors have carried out ethnographies on life cycle practices at the corporate level (Freidberg, 2015; Nilsson-Lindén et al., 2021), Paper II presents to my knowledge the first ethnography on LCA use within a product development project. The ethnographic approach enabled Paper II to contribute detailed descriptions of everyday LCA-based practices that contrast and complement a stylised understanding of decision-making as understood in the conventional linear model.

Paper II identified and contributed empirical evidence for identifying six effect mechanisms that deviate from a linear causal relationship between LCA study and decision-making. These effect mechanisms add detail to a better understanding of the substantive effectiveness of LCA use and highlight the limitations of a linear model of LCA use. These findings support existing claims that practitioners need to balance the scientific quality of LCA knowledge with considerations of practical utility (c.f. Baitz et al., 2013; Freidberg, 2015; Rex et al., 2020). In addition, Paper II contributed three alternative models of LCA use – a complex knowledge-based model, a linear activity-based model, and a complex activity-based model of LCA use. The models support LCA practitioners and researchers in guiding their efforts in understanding and addressing the complex sequence of events through which substantive effects emerge in product systems.

Paper III presented a longitudinal study of LCA-based practices at four Swedish building companies between 2017 and 2025. The longitudinal episodic approach enabled the study to present evidence on the evolution of LCA-based practices during a formative period for the sector. The LCA developed from being a mostly novel method in building companies in 2017 to being routinely used in 2025.

The longitudinal approach contributed a detailed empirical account of the evolution of LCA-based practices in building companies. This study complements longitudinal empirical studies carried out in other domains (Freidberg, 2015; Nilsson-Lindén et al., 2021; Tessitore, et al., 2025) by adding empirical detail on the *evolution* of LCA-based practices in a building context that was predominantly limited to survey data for environmental work (Gluch, Gustafsson, Thuvander, & Baumann, 2014). The findings support a three-phase institutional trajectory that has been previously used to understand LCA adoption in other organisations (Baumann, 1998; Frankl & Rubik, 2000) as well as organisational learning pathway identified by Tessitore *et al* (2025).

The period between 2017 and 2025 has been characterised by the development and subsequent implementation of a legal requirement for LCA-based climate declarations for new-build projects in Sweden. The empirical findings in Paper III therefore shed light on the influence of legislation-driven LCA applications in a building context. Despite a growing interest in LCA-based policies and legislation (Jegen, 2024; Sala et al., 2021; Sonnemann et al., 2018), little empirical attention has been given to the microlevel effects of these legislations on existing LCA practices in companies affected by such legislation.

In particular, the findings provide evidence for the development of a variety of LCA-based practices existing in parallel with climate declarations. The potentially stimulating effect of legislation-driven LCA applications on other LCA-based practices contrasts with previous findings in relation to the renewable energy directive (RED), where the studied biofuel companies were primarily seen as reducing their LCA practices to the legal requirements (Lazarevic & Martin, 2018). To support effective LCA-based practices, it is vital that regulations do not stifle the capacity of companies to carry out multiple LCA-based practices side-by-side.

7.3 Implications

The research concluded that LCA practices in full account, cannot be reduced to models or reported product environmental impacts. What can be perceived as desirable outcomes from a science-based perspective are also incomplete accounts of LCA practices. By empirically researching LCA-based practices, this dissertation was able to show how concerns of scientific credibility are insufficient to explain how LCA works in sustainable building. In particular, this dissertation highlights the value of practical utility for understanding how building environmental impacts are addressed and understood. Consequently, it is suggested that a pragmatist philosophy could direct efforts in the LCA community toward a more explicit consideration of practical usefulness and effectiveness in LCA. This section will explicate the implications of these conclusions for how LCA is practised, taught, and the kind of research that is carried out.

LCA practices

Throughout the research, I frequently observed a disconnect between the science-based discourse present in the LCA community and experiences of how LCA was practised in the studied building context. On several occasions, interviewed or observed LCA practitioners showed concern and even a slight embarrassment that their work did not live up to the scientific norms that they rightfully or wrongfully perceived to be associated with LCA. To these individual practitioners, the findings of this research may help soothe the mind. Rather than them falling short of scientific ideals, the research findings suggest that a pre-occupation with scientific credibility may lead to a distorted image of what LCA is and how it is practised.

Currently, the relation between LCA and practical utility is ambiguous. While the ISO 14040/44 standards identify the importance of practical application contexts for carrying out LCAs, they are of limited use for handling the variety that this generates. The ISO 14040 standard attempts to address the issue by explicitly placing the application of the results themselves outside the scope of the standard (ISO, 2006a, p.1), allowing a demarcation of a more science-based LCA from its social application in LCT or LCM (Sonnemann & Margni, 2015). The ambiguous relationship of LCA with practical utility is further illustrated by the proliferation of LCA-based standards in different application contexts (c.f. Beemsterboer et al., 2020), attempting to provide ever more finely grained methodological rules to satisfy the scientific credibility of the method.

While a science-based LCA is expected to lead to more accurate results, it also tends to reify scientific norms in ways that are not necessarily supportive of better or more useful LCA outcomes in industry practices. A pragmatist approach to LCA can therefore support a more realistic image of what LCA is by placing concerns of practical utility more central in LCA.

Experienced LCA practitioners are aware of the continuous tension in their work between maintaining credibility and usefulness (c.f. Baitz et al., 2013; Freidberg, 2015; Rex et al., 2020). The findings in this dissertation do not provide a magic solution that dissolves the problem. Instead, it is recommended that LCA practitioners, insofar they are not doing so, explicitly recognise this tension and be transparent about what LCA can and cannot contribute with. By addressing concerns of practical utility, practitioners may more effectively plan LCA work in relation to available analytical resources and find additional ways to address product environmental impacts.

LCA research

While practical utility may be an ambiguous concept in LCA practices, it has remained an immaturely developed concept in LCA research. Hence, the academic LCA community is urged to reflect on the opportunity costs of maintaining the scientific credibility of LCA. This may come with a recognition that measures supporting scientific rigour are not intrinsically good, or do they necessarily contribute to the practical utility of LCA.

Compared with the wealth of research on LCA results, methods, tools, and data there remains a scarcity of research that explicitly analyses how LCA is actually practised – i.e. carried out, used, organised – in practical contexts (c.f. Freidberg, 2015; Lazarevic & Martin, 2018; Rex et al., 2020; Tessitora et al., 2025; Testa et al., 2022). It is therefore recommended to carry out more practice-oriented LCA research (c.f. Moncaster et al., 2023; Niero et al., 2021; Nilsson-Lindén et al., 2021). In this context, a pragmatist philosophy of LCA may be useful for developing research that is appreciative of the practical opportunities and constraints of LCA in understanding and addressing product environmental impacts. In addition to practice-based studies, it would be useful for LCA researchers to discuss goal, context, and purpose more transparently in regular LCA studies (c.f. Nyqvist, Baumann, Shavalieva, & Janssen, 2025).

LCA education

Given the significance of the results for LCA practice and research, it may be sensible to spell out some implications for teaching LCA to future practitioners and researchers. The way that LCA is understood influences how it is taught. For example, a more contextually sensitive textbook (e.g. Baumann & Tillman, 2004) looks rather different from a more method-oriented textbook (e.g. Klöpffer & Grahl, 2014) despite both being used to teach LCA. While understanding that there is range of technical competences that have to be taught in LCA (c.f. Viere et al., 2021), it would be recommended not to undervalue the practical context in which LCA is practised.

7.4 Research outlook

Future research is suggested to examine the use of pragmatist philosophy for different LCA practices and domains. In doing so, there are a few research avenues that are especially relevant to point out because they allow addressing issues that were not addressed in this dissertation but that are relevant for understanding and developing considerations of practical utility in LCA.

First, power dynamics were not explicitly analysed in this dissertation. Power dynamics matter in building projects as they influence the ways in which environmental problems and solutions are structured (Moncaster, 2012). The studied projects presented cases where climate calculations were used to support concrete-based solutions. While this was perceived in the projects as evidence of an inherent material neutrality in the LCA tool, this is not necessarily so. Moncaster and Malmqvist illustrated how the concrete and cement industry in Sweden has used LCA in an effort to defend their market share (2020). Such an explicit concern for power dynamics could help critically examine the value of practical utility in LCA.

Second, the empirical research focused primarily on LCA practices in relatively well-structured problem situations. Although building projects also carry different types of complexity (c.f. Beemsterboer, 2019), the identified sustainability improvements connected to LCA practices in the studied building projects were relatively straightforward, and not subjected to controversy. To test the robustness of a pragmatic approach in LCA, it would be worthwhile to examine how a concern for practical utility would fare in situations where it is more uncertain whether a particular course of action will reduce product environmental impacts or where there exists disagreement on the goals to pursue (c.f. Tukker, 1999). Recent concerns about the environmental impacts of slag in infrastructure projects illustrates that the construction sector is certainly not immune to environmental controversies (ILT, 2025).

Third, the research carried out in this dissertation focused exclusively on attributional LCA, as did the studied building LCA practices. Given the importance of practically conceivable effects for pragmatism, it may be worthwhile to examine the connection to consequential LCA more explicitly (c.f. Schaubroeck, 2023). Although pragmatism and consequential LCA approach practical effects differently, it would be relevant to learn how practical utility relates to consequential LCA practice.

Finally, concerns of practical utility and context are complex phenomena to account for, interweaving with LCA practices in every direction. While such considerations are useful for understanding and addressing product environmental impacts, it remains an altogether different thing to fully understand these relationships. Rather than exhausting this research topic in this thesis, I have made an empirically informed case for why these issues matter to LCA. Further research is recommended to deepen and systematise the knowledge in this domain.

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