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Beyond compliance in legislation-driven life cycle assessment: a cross-case analysis of building-specific LCA practices within four Swedish building companies between 2017 and 2025

Sjouke Beemsterboer [a,*], Henrikke Baumann [b], Holger Wallbaum [a]

[a] Sustainable Built Environments, Chalmers University of Technology, Gothenburg, 412 96, Sweden
[b] Environmental Systems Analysis, Chalmers University of Technology, Gothenburg, 412 96, Sweden

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ABSTRACT

Despite increasing popularity of LCA in policy circles, few empirical studies aim to understand how legislative developments influence existing LCA-based practices within targeted organisations. This paper examines the development of building-specific LCA practices at four Swedish building companies between 2017 and 2025, a period in which legal requirements for building climate declarations were introduced. The results show a remarkable increase in the volume and variety of LCA-based practices in building projects. The studied cases successfully moved beyond legal compliance by carrying multiple LCA-based practices in parallel. The importance of multiple LCA-based practices for sustainable building implies that caution is advised when developing novel LCA-oriented legislation. Stricter regulations may have unintended negative effects on sustainable building when the capacity of organisations to align LCA use with other legitimate concerns in building projects is stifled. Paying closer attention to the effects of legal requirements on existing LCA-based practices is therefore recommended.

1. Introduction

Currently, the use of environmental life cycle assessment (LCA) is evolving from being a voluntary and market-driven practice that focuses on environmental innovation and learning to becoming increasingly mandated by governing authorities (e.g. Jegen, 2024; Sala et al., 2021). Legislation-driven LCA applications are motivated by the ambitions of governing authorities to address environmental problems, such as human-induced global warming. The legislative measures tend to carry detailed methodological standards that structure how and when LCA is to be conducted (c.f. Lazarevic and Martin, 2018). However, for legislation and the accompanying methodological standard to reach the intended effect, it is important that they (1) effectively harmonise LCA practices in a field and (2) that such harmonised LCA practices have positive substantive effects – i.e. contribute to changes in product systems that reduce life cycle environmental impacts.

Despite the growth of legislation-driven LCA practices, few empirical studies have investigated how LCA-oriented legislation reshapes LCA practices. Most notably, Lazarevic and Martin (2018) identified a positive, although not desirable, harmonising effect from the European Renewable Energy Directive (RED) in reducing LCA practices in biofuel organisations to compliance with the methodological rules prescribed in the directive. Outside the context of legislation-driven LCA, Rex and Baumann (2008) reported that organisations in structurally similar conditions may adopt diverging LCA practices due to contingencies and personal interpretations of different actors. Institutional theory suggests that regulations recursively constrain and make possible activities of involved agents (Giddens, 1984; Scott, 2013), influencing practices in ways that may be difficult to predict in advance.

In light of the current state of knowledge, it remains unclear whether recent support for legislation-driven LCA applications as an environmental policy instrument is a desirable development for existing LCA practices in affected organisations. The lack of attention to possible unintended negative side effects of LCA-oriented regulation is especially problematic given that the building sectors in several countries are currently facing legislation-driven LCA applications as well as the introduction of limit values for greenhouse gas (GHG) emissions (Barjot and Malmqvist, 2024; Boverket, 2023).

To better understand the effects of legally mandated LCA practices, this article examines the development of building-specific LCA practices

* Corresponding author.
E-mail addresses: sjouke@chalmers.se (S. Beemsterboer), Henrikke.Baumann@chalmers.se (H. Baumann), holger.wallbaum@chalmers.se (H. Wallbaum).

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within four Swedish building companies between 2017 and 2025. Throughout this period, the studied companies saw the creation and implementation of a law mandating LCA-based climate declarations in the production of new buildings. While the introduction of mandatory LCA-based climate declarations for buildings was based on widespread support in Swedish politics and industry (von Malmborg et al., 2024), it was initially unclear whether the introduction of legally mandated climate declarations would contribute to more sustainable building practices (Sadri et al., 2022). The effects of LCA-oriented legislation on LCA practices are important to examine because compliance with the law risks reducing the freedom to practice LCA as companies see best fit (c.f. Beemsterboer et al., 2025; Lazarevic and Martin, 2018).

This research seeks to answer the following research questions:

RQ 1. How did the studied building companies develop building-specific LCA practices between 2017 and 2025, a period during which a legal requirement for building climate declarations was introduced?

RQ 2. How did the introduction of a regulatory methodological standard reshape the variety and characteristics of building-specific LCA practices within the studied building companies?

By studying the development of LCA use in response to an evolving institutional landscape, it becomes possible to better understand the intended and unintended effects of legislation-driven LCA applications on LCA and LCA-based practices in affected organisations. By extending the focus to LCA-based practices, this research accepts that there is a spectrum of LCA-related knowledge and activities that may contribute to understanding and addressing product environmental impacts in addition to what is conventionally recognised as LCA. Here, LCA-based practices include (1) conducting LCA studies and related climate calculations, (2) using assessment outcomes, activities, and life cycle thinking (LCT) in building planning, design and construction practices, and (3) a range of direct and indirect supporting activities that help develop LCA practices in an organisation.

While LCA may be usefully practised by different actors along the building product chain – e.g. architects, property developers, and material suppliers – this research focused on building companies because of the central coordinating role that these organisations carry in the building process in Sweden. Building companies – also described as contractors or construction companies – are primarily responsible for constructing buildings for clients in accordance with the agreed-upon contractual and legal requirements (Gray and Hughes, 2001; Hansson et al., 2015). In addition to the core business of contracting, larger building companies tend to develop additional building-related activities, including property development, building design, material supply, and property management. Although property developers are formally mandated to fulfil the legal requirement for LCA-based climate declarations in Sweden (Boverket, 2024), building companies are often responsible for ensuring that this legal requirement is fulfilled in practice.

2. Theory

Although building LCA has been identified as a quickly growing field of research (Fnais et al., 2022; Roberts et al., 2020), knowledge of industry-based LCA practices remains limited. So far, the development of LCA practices in the building industry has been perceived to be hindered by a lack of data availability, methodological issues (De Wolf, Pomponi and Moncaster, 2017), and a lack of market and regulatory demands for LCA (e.g. Francart et al., 2019; Moncaster et al., 2023). In this context, the introduction of legislation-driven LCA applications with accompanying methodological standards can be understood as a potentially important development to stimulate LCA-based practices in the building sector.

2.1. Voluntary and mandatory LCAs

Although the use of LCA in policies is not a novel phenomenon (Sala et al., 2021; Sonnemann et al., 2018; Säynäjoki et al., 2017), the impact of legislation on existing LCA practices remains understudied. LCA is one of several environmental instruments that can be chosen by policy makers, ordered on a scale from voluntary information-based instruments to coercive regulations that ban specific technologies and production methods (Graedel and Allenby, 2010). Historically, LCA has been characterised as a voluntary information-based instrument that is market driven and used by companies to understand and address product environmental impacts (Baumann and Tillman, 2004).

Market-driven LCA adoption may support internally as well as externally oriented LCA applications in organisations (Baumann, 1998; Berkhout, 1996). Eco-design, product development and other forms of research and development (R&D) are examples of internally oriented LCA applications and leave a high degree of freedom to practitioners (Baumann and Tillman, 2004; McAloone and Pigosso, 2018; Sandin et al., 2014). Environmental Product Declarations (EPDs), product marketing, and other forms of consumer information are examples of externally oriented LCA applications (Baumann and Tillman, 2004; Frydendal et al., 2018).

Externally oriented LCA applications are typically subjected to stricter methodological rules than internally oriented applications – i.e. ISO standards, sectoral standards, and product category rules. For example, LCAs that make comparative assertions between different products are governed by the ISO 14040 standard and require independent third-party review (ISO, 2006). In addition, research on standardisation has shown that widely adopted voluntary standards exert pressure on nonadopter users to conform (Bowker and Star, 2000; Brunsson and Jacobsson, 2002; Busch, 2011).

In recent years, the LCA community has witnessed an evolution that shifts LCA from being a market-driven practice towards becoming more legislation-driven, owing to the introduction of LCA as a policy instrument in different societal domains (e.g. Jegen, 2024; Lazarevic and Martin, 2018; Sala et al., 2021; Sonnemann et al., 2018). In the European Union, governing authorities are increasingly relying on LCA-based policy instruments to address environmental concerns related to products and services. For buildings, a drive towards legislation-based LCA applications is connected, among other things, to the energy performance of building directive (EPBD), construction product regulation (CPR), and the EU taxonomy for sustainable activities (Regulation, 2020; Directive 2024/1275, 2024a; Regulation, 2024). In addition, the European Commission has launched the product environmental footprint initiative (PEF) and Level(s) to support a methodological harmonisation of (building) life cycle environmental information (European Commission, 2018, 2025).

At the national level, several European countries have already started to require LCA-based declarations for new building projects (Barjot, 2024; Boverket, 2023). For example, Denmark, France, and the Netherlands have all introduced legalisation, mandating that LCA-based declarations be obtained in connection with new building projects (MTE, 2024; Rijksoverheid, 2024; Rikstinget, 2021). In Sweden, the National Board of Housing, Building and Planning (*Boverket*) introduced mandatory declarations of climate impacts for all new building projects over 100 m2 in 2022 (Boverket, 2024). In addition to producing environmental information, these legislation-driven LCA initiatives are moving toward the subsequent introduction of limit values for buildings. The evolution from market-driven to legislation-driven LCA applications matters, as it introduces an obligation to carry out particular types of LCA studies following a methodological standard prescribed by authorities. This potentially reduces the freedom for LCA practitioners to carry out LCA practices as they see fitting (see Table 1).

For the time being, it is unclear whether a more explicit structuring of LCA practices through legislation-driven LCA applications is a desirable development. On the one hand, the LCA community has witnessed a

Table 1
Market-driven and legislation-driven LCA applications ordered by the degree of methodological standardisation and freedom given to LCA practitioners.

Types of LCA applications	Examples	Degree of methodological standardisation	Degree of freedom LCA practitioners
Market driven, internal orientation	Eco-design, R&D	Low	High
Market-driven, external orientation	EPD	↑	↑
Market-driven, external orientation	Comparative assertions		
Legislation-driven	Climate declarations (SE)	↓	↓
Legislation-driven, with limit values	Climate declarations (DK)	High	Low

long history of methodological harmonisation and typically displays a positive attitude towards the standardisation of LCA practices (e.g. Bjørn et al., 2018; Hauschild et al., 2018). The subsequent reduction of methodological freedom to LCA practitioners that methodological standards bring is deemed useful for improving the scientific credibility and comparability of LCA results. On the other hand, the scarce empirical evidence that exists gives reason to be concerned. In particular, Lazarevic and Martin (2018) show how the Renewable Energy Directive reduced LCA practices within the Swedish biofuel sector to compliance with the prescribed methodological standards. Consequently, legislation-driven LCA applications came at a cost of internally oriented LCA applications that were deemed important for reducing product environmental impacts.

Outside the context of LCA, Testa et al. (2011) reported that direct regulation rather than information-based environmental management systems (EMS) was correlated with innovation and green business performance for a sample of building and construction companies in Italy, France, and the Netherlands. However, Daddi et al. (2016) reported that coercive pressures were not correlated with the environmentally effective use of an EMS, suggesting that legislative pressure stimulates the ceremonial adoption of an EMS regardless of its use for environmental innovation. Also here, there appears to be an ambiguous relationship between regulation and information-based environmental instruments.

2.2. *Understanding the institutional pressures of legislation on organisations and practitioners*

Given the relative shortage of empirically informed research on the topic, it is worthwhile to look at institutional theory to better understand the potential effects of legislation-driven LCA applications on LCA-based practices in building companies. Institutions commonly shape behaviour by prescribing, suggesting or constraining particular courses of action, which in turn recursively shapes the form of institutions (c.f. Giddens, 1984). In this context, a distinction can be made between regulative, normative, and cultural-cognitive institutional pillars (Scott, 2013). A legal requirement is a classic example of a regulative institution and is characterised by (1) an explicit codification of the regulated practice and (2) the involvement of an authority that can enforce compliance.

In doing so, it is relevant to recognise that the effects of institutions are not predetermined. The complex, recursive relationship between institutions and reflexive agents may inspire similarity as well as differences in practices that may be difficult to predict in advance (c.f. Giddens, 1984). In this interactive process, organisations are thought to play a mediating role between societal institutional pressures and the activities of individual actors (Scott, 2013). Organisations provide a certain protection from institutional pressures but also develop internal institutions that enable and constrain the behaviour of individuals. Because organisations in a field share a similar institutional context, it has been suggested that organisations may become more similar in time, a process referred to as isomorphism (DiMaggio and Powell, 1983). At the same time, it has been recognised that interactive dynamics may also promote heterogeneity among organisational responses (Hoffman and Ventresca, 2002; Milstein et al., 2002).

In the context of the voluntary and market-driven adoption of LCA in organisations, institutionalisation processes have previously been characterised as a three-phase process reflecting different levels of maturity (Baumann, 1998; Frankl and Rubik, 2000): (1) habitualisation, the introduction of an LCA as a new method used by knowledgeable adopters with a focus on learning. (2) Objectification: where LCA use spreads through organisations, diversifying uses and focusing on decision making. (3) Sedimentation: where organisational LCA-based structures are developed that support and guide LCA practitioners. Because LCA-based structures reduce the expertise required to carry out or use LCA, they allow LCA-based practices to spread throughout the organisation.

More recently, Tessitore et al. (2025) produced a four-stage institutionalisation trajectory based on the experiences of a company with LCA and life cycle management (LCM): (1) drawing on LCA, (2) triggering a process of identity change, (3) reshuffling organisational tasks, and (4) reconfiguring business strategy. Although both frameworks are well suited for describing the progressive development of LCA practices in companies over time, they remain limited in explaining the sources of variation regarding LCA practices within and between companies in a field. Furthermore, these institutionalisation processes have not been studied explicitly in relation to the introduction of legislation-driven LCA applications.

On the basis of the literature addressed, it becomes apparent that there is uncertainty regarding the effects of legislation-driven LCA applications on LCA-based practices in affected organisations. Legislation may stimulate LCA-based practices by requiring organisations to carry out particular types of LCA studies while simultaneously risk reducing LCA-based practices in organisations to compliance with regulatory standards. Moreover, institutional theory suggests that companies may respond differently to shared institutional pressure. Importantly, the reflexive behaviour of individuals in organisations may lead to the development of different types of LCA practices (c.f. Rex and Baumann, 2008). Given the difficulty in predicting how LCA-based practices develop in response to the introduction of LCA-oriented legislation, it is necessary to empirically investigate this matter.

3. Method

The research design was based on a longitudinal episodic approach (Pettigrew, 1990) following a nested-case study method (Yin, 2009). Four building companies and nine building projects were studied between 2017 and 2025, a period in which LCA-based climate declarations became a mandatory requirement in the permit process of new building projects (2022). The study highlights experiences with building-specific LCA-based practices at three large building companies (>5000 employees) with operations throughout Sweden (*Alpha, Beta, Gamma*), as well as one medium-sized building company (250-500 employees) with operations in West and South Sweden (*Delta*). The comparative perspective allowed to examine different responses within these organisations to the (anticipated) introduction of a shared legal requirement for building climate declarations.

The study focused on LCA-based practices related to new building projects in Sweden, aligning with the legislation on building climate declarations. Consequently, the study was delimited to the domestic building segments of the companies. Other business segments were excluded from the study – e.g. infrastructure and international markets. This methodological choice was supported by the strong organisational boundaries between the business segments in the studied companies.

With the exception of a few R&D-related activities, LCA-based practices for buildings in Sweden unfolded within the domestic building segments. The focus on building-specific LCA also implied that practices focusing on the environmental impacts of companies – e.g. corporate sustainability reporting and organisational LCA – where excluded from this study.

Acknowledging that change is a continuous process, the research was based on episodic engagement with the studied organisations (c.f. Pettigrew, 1990). The episodic research design fits with the analytic purpose of tracking differences in building-specific LCA practices over time and comparing the responses to building climate declarations between organisations. Nonetheless, it should be emphasized that the change *processes* themselves cannot be investigated through episodic engagement. In combination with the absence of a counterfactual – i.e. the continued absence of legislation – the episodic engagement implies that no formal causal effect will be inferred from the legislation on the observed LCA-based practices.

Given these limitations, a nested case study approach was chosen to recognise the reciprocal relationship between LCA-based practices in temporary building projects and more continuous building-focused LCA developments at the company level. Here, the research design anticipated the relevance of project- and company-level interactions for understanding innovations and environmental work in building (c.f. Gluch and Räisänen, 2012; Winch, 1998).

Given the relative novelty of LCA as a method for understanding and addressing environmental concerns in building projects, cases were selected with the intention to maximise learning opportunities (c.f. Flyvbjerg, 2006; Stake, 1995). To do so, the research was carried out within building companies that were practising LCA or that expressed early interest in doing so. The nine building projects selected were perceived by the respective companies to have average or high LCA-related ambitions. Consequently, the research presented in this study does not provide a representative picture of the population of Swedish building companies or projects. Instead, it presents cases where there was an interest in practicing LCA.

3.1. Data collection

Data collection took place between 2017 and 2025 and focused on three data collection moments, representing three developmental states in relation to the legal requirement on LCA-based climate declarations. In 2017, a pre-study was initiated to examine the initial state of LCA practices in the studied building companies, a few months before the Swedish state would make public its intention to introduce LCA-based climate declarations. In 2021, a first round of case studies was carried out to examine LCA practices the year before the legal requirements entered into force. Around the beginning of 2025, a second round of case studies was initiated to examine LCA practices nearly three years after the legislation on climate declarations took effect (see Fig. 1).

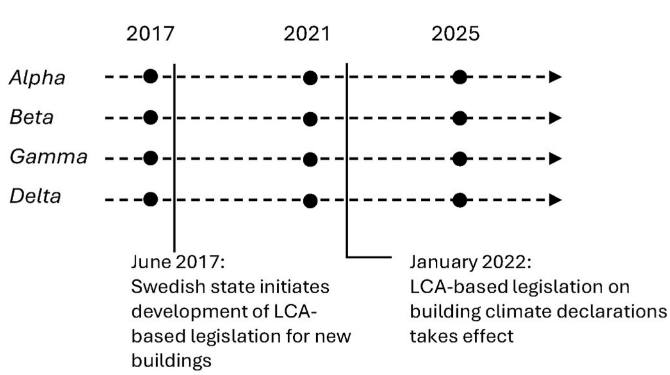

Fig. 1. Three moments of data collection at four Swedish building companies in relation to the initiation and enactment of LCA-based legislation on building climate declarations.

Data collection was oriented toward providing credible accounts of LCA-based practices in the studied cases (c.f. Stake, 1995). Data were collected from semi-structured interviews (n = 34), LCA-based climate calculation reports, and additional project- and company-level documentation. The reported outcomes from the LCA-based climate calculations were instrumental as a starting point for tracing LCA-based practices in building projects and organisations. Notably, all the studied LCA-based practices focused on attributional LCA.

The interviews were conducted with key practitioners for climate work in the projects (see Table 2), including LCA analysts (n = 10), LCA specialists (n = 4), sustainability managers (n = 6), cost engineers (n = 4), project managers, site managers, internal clients (n = 6), and external clients (n = 4). Note that in practice, there can be a degree of overlap between different roles – e.g. LCA specialist and sustainability manager. Five practitioners were interviewed more than once – i.e. sustainability manager$^{\#3}$, sustainability manager$^{\#5}$, LCA analyst$^{\#5}$, LCA analyst$^{\#7}$, and LCA analyst$^{\#9}$. Six interviews were carried out with two interviewees simultaneously. The interviews typically lasted between 60 and 90 min and consisted of face-to-face (n = 18) and video-based interviews (n = 16). The interviews were tape-recorded and transcribed.

The interviewees were asked to describe in detail how specific LCA-based activities were performed, a technique known as interviewing the double (c.f. Nicolini, 2009). The LCA-based climate calculation reports and reported reductions in building climate impacts provided a background against which the interviews took place. Typically, 3-4

Table 2
Data collection from interviews in the studied projects and companies.

Company	Year	Case study	Ambition	Interviews	
				#	Interviewee role
Alpha	2017	-		1	Sustainability manager$^{\#1}$, LCA analyst$^{\#1}$
				2	LCA analyst$^{\#2}$
				3	Sustainability manager$^{\#2}$
	2021	Alpha21	Average	4	LCA analyst$^{\#3}$
	2024/25	Alpha25	High	5	LCA specialist$^{\#1}$
				6	LCA analyst$^{\#4}$
				7	Site manager$^{\#1}$
				8	External client$^{\#1}$, External client$^{\#2}$
Beta	2017	-		9	Sustainability manager$^{\#3}$, LCA analyst$^{\#5}$
				10	Sustainability manager$^{\#3}$, LCA analyst$^{\#5}$
	2021	Beta21	High	11	LCA analyst$^{\#6}$
				12	Cost engineer$^{\#1}$
				13	Project manager$^{\#1}$
	2025	Beta25	Average	14	LCA specialist$^{\#2}$
				15	Cost engineer$^{\#2}$
				16	Site manager$^{\#1}$
Gamma	2017	-		17	LCA specialist$^{\#3}$, LCA analyst$^{\#7}$
				18	LCA analyst$^{\#7}$
	2021	Gamma21	High	19	LCA analyst$^{\#8}$
				20	Project manager$^{\#2}$
				21	Client, internal$^{\#1}$
	2025	Gamma25	Average /High	22	LCA specialist$^{\#4}$
				23	Cost engineer$^{\#3}$
				24	Client, internal$^{\#2}$
Delta	2017	-		25	Sustainability manager$^{\#4}$
				26	Sustainability manager$^{\#5}$
	2021	Delta21a	High	27	Sustainability manager$^{\#5}$
				28	LCA analyst$^{\#9}$
				29	Client external$^{\#3}$
		Delta21b	Average	30	LCA analyst$^{\#9}$
				31	Cost engineer$^{\#4}$
	2025	Delta25	Average	32	Sustainability manager$^{\#6}$ (= LCA analyst$^{\#9}$)
				33	LCA analyst$^{\#10}$
				34	Client, external$^{\#3}$, Client, external$^{\#4}$

interviews were caried out in each building project to give space for different experiences to be expressed. Project- and company-level documentation were collected to prepare interviews and to support triangulation during the analysis process. Document collection was guided by individual case needs (Stake, 1995), and included project-internal reports, company-internal documents, year reports, press releases, and research papers.

3.2. Analysis

To support credible accounts of LCA-based practices in the studied cases, the analytic process started by developing empirically grounded case descriptions of the studied LCA-based practices in the individual projects and companies. While experiences in the projects were leading, the categorisation of the empirical data was loosely structured around pre-existing concepts (c.f. Alvesson and Sköldberg, 2009; Stake, 1995). Following a practice theoretical approach (c.f. Nicolini, 2012), activities belonging to LCA-based practices were used as thematic categories to order the data – e.g. goal setting, data collection, use of results in projects.

Triangulation of different data sources allowed to corroborate interviewees' statements about LCA-based practices, their relation to building design and construction practices in the studied projects, and to company-specific LCA developments. To ensure credibility, care was taken to gather additional data sources when statements were subject to interpretation or critical to a case (Stake, 1995). The primary analytical process resulted in four case-descriptions of LCA-based practices, with projects being nested within a company account, and chronologically ordered from 2017 to 2025.

On the basis of the individual case descriptions, a cross-case analysis focused on similarities and differences between LCA-based practices in studied projects and companies between 2017 and 2025. While structural similarities across LCA-based practices and building projects allowed for a degree of coherence between the cases, care was taken not to exclude any company- or project-level idiosyncrasies from the individual case descriptions. The resulting cross-case account of the development of LCA-based practices in the studied projects and companies is presented in section 4. On the basis of this cross-case account, the development of LCA-based practices and their relation to the regulatory methodological standard were examined and discussed in section 5.

4. Building-specific LCA practices within four Swedish building companies between 2017 and 2025

This section presents a cross-case chronological account of building-specific LCA practices within the studied cases for the years 2017, 2021, and 2025. For each moment in time, this section presents (1) the status of LCA in the Swedish building sector, focusing on the legislation on building climate declarations, (2) the development of LCA in the studied building companies, and (3) LCA-based practices in the studied building projects.

4.1. Initiating building LCA in building companies - 2017

In 2017, many organisations in the Swedish building sector were alerted to the potential of LCA as a method for sustainable building. The Swedish government instructed the National Board of Housing, Building and Planning (*Boverket*) to investigate whether there is a need to update the Swedish Planning and Building Act (Plan-och bygglag, 2010:900) so that it would become a more effective instrument for reducing climate impacts (Regeringskansliet, 2017a). Having mapped the existing state of knowledge on building climate impacts from a life cycle perspective (Boverket, 2015), *Boverket* was subsequently instructed by the government to develop a proposal for an LCA-inspired methodology to address building life cycle climate impacts (Regeringskansliet, 2017b). The proposal was inspired by the experiences of the Swedish Transportation Authority in demanding LCA-based climate calculations in specified infrastructure projects (Trafikverket, 2015).

At the time, the building sector was far from ready to routinely carry out building LCAs. There were few dedicated building LCA tools available on the market and no publicly accessible Swedish database with Global Warming Potential (GWP) values for construction materials and products. The Finnish company Bionova had developed the commercially available One Click LCA tool. In the summer of 2017, the Swedish environmental consultancy company IVL released a free building climate calculation tool (BM) with Swedish GWP values for main construction materials (Erlandsson, 2018).

4.1.1. LCA practices in the building companies (2017)

Despite a growing interest in understanding building life cycle climate impacts, most building companies had little to no practical experience with carrying out building LCAs. At the beginning of 2017, *Beta* and *Delta* reported no prior experience with carrying out LCAs or climate calculations on their building projects. *Alpha* had carried out a few exploratory LCA studies on building designs using the One Click LCA tool. For the time being, building environmental performance was gauged primarily through mandatory operational energy calculations and the voluntary use of building environmental certification schemes.

In 2017, *Gamma* was the only company that routinely carried out LCA-based climate calculations. *Gamma* had invested in the appropriation of a semi-automated climate calculation software, linking building data from the company's own cost estimation software to generic environmental data from a proprietary climate database. Despite relying on partially quantified resource inventory lists available within the cost calculation software, *Gamma* was able to produce LCA-based climate calculations covering the product level of buildings by using cost-based average material quantities for parts of the building where specific material quantity data were not available (A1-3 according to CEN, 2011), for example, due to sub-contracting practices. Despite apparent shortcomings regarding the inventory data used, the LCA-based climate calculations were perceived to be of acceptable quality to the practitioners involved.

With respect to the capacity to carry out LCA studies, the building companies also reported varying availability of personal resources dedicated to climate work. *Beta* and *Delta* had no dedicated climate analysts in their environmental sustainability units. *Alpha* had recently started organising a building LCA group by newly appointing a climate coordinator and junior climate analysts on a part-time basis. In line with a more developed building LCA practice, *Gamma* had already developed a more stable organisational structure with dedicated building climate analysts and an experienced research and development manager to support the internal development of building LCAs.

A common strategy for developing LCA competences in the studied building companies was to become involved in external research projects on building LCA. For Alpha, *Beta* and *Delta,* competence development focused on gaining familiarity with the LCA method, understanding the requirements and processes for data collection, and learning about the hotspots of building life cycle climate impacts. Fitting with a more extensive LCA practice, *Gamma* was able to take a more ambitious approach and took a leading role in research and development projects that helped shape the landscape of building LCA in Sweden. Internally, *Gamma* also aimed to develop a process for digital data collection on building resources and improve the accuracy and comparability of LCA-based climate calculations.

4.1.2. Relation to building projects (2017)

In all companies, learning about LCA and building environmental impacts remained a central motivating factor, with LCA being intricately linked to research and development efforts. At *Alpha, Beta,* and *Delta,* no direct relationship could be established between the initial LCA-based activities and their application in specific building projects, although *Alpha* had used building quantity data from actual projects in a few exploratory LCA-based climate calculations.

At *Gamma*, a developed routine of carrying out building climate calculations on building projects created an important condition for using building LCA more actively to address building environmental impacts. In addition, *Gamma* had communicated a strategy document specifying the company's climate ambitions, including a 50% reduction in CO2e emitted throughout the value chain by 2030 and net-zero carbon emissions by 2045. To complement these goals, the company had developed an internal framework for environmental targets that was to be used by building projects.

4.2. In preparation for LCA-based climate declarations (2021)

Four years later, the building sector was preparing for the introduction of mandatory LCA-based climate declarations to enter into force in January 2022. The legislation would also introduce a specification of a methodological standard developed by Boverket in consultation with academic, industry and societal stakeholders (see von Malmborg et al., 2024 for a detailed analysis of the policy process).

The new law stipulated that LCA-based climate declarations would have to be carried out as part of the requirements set in the building code to obtain final approval from the relevant authorities – i.e. that the conditions for obtaining the building permit had been met. The scope of the climate declarations included the building's climate shell, load bearing system, and inner walls (parts 2-6 according to BSAB83). Furthermore, it included building life cycle modules up to the construction phase (A1-5). Building climate impacts would have to be expressed in a functional unit of 1 m2 gross-floor area (GFA) and calculated for global warming potential-greenhouse gas (GWP-GHG). To carry out climate declarations, Boverket had released a Swedish database with generic climate values for 150 of the most commonly used building materials and products. Except where EPD data were used, climate declarations would have to be calculated with conservative values that had 25% higher GWP values compared to typical values available in the database (Boverket, 2024). To enhance the credibility of the results, climate declarations would have to be supported by verified resource data and EPD data where applicable and be adjusted for gaps in data coverage.

The publication of an openly accessible Swedish dataset spurred numerous developments that supported the development of LCA practices. Existing building LCA tools from IVL and Bionova had been adapted to include Boverket's building data. In addition, new LCA-based climate tools were being developed to support climate calculations based on cost estimation data, building information models (BIMs), and planning parameters.

A few years prior, in 2018, the building sector agreed on a joint road map for fossil-free competitiveness (Fossilfritt Sverige, 2018). This sectoral strategy document expressed the commitment of the signatories, including all the studied building companies, to commit to a shared pathway towards net-zero greenhouse gas emissions in the sector by 2045. From an LCA perspective, the document stated that key players in the sector would map climate emissions within the organisation and the product value chain by 2022, achieve a clear reduction in greenhouse gas emissions by 2025, and a 50% reduction in greenhouse gas emissions by 2030 (Fossilfritt Sverige, 2018).

4.2.1. LCA practices in the building companies (2021)

After a learning period, the studied building companies became increasingly competent in carrying out LCA-based climate calculations. By 2021, all the building companies had internal resources available to carry out LCA-based climate calculations. *Gamma* continued to demand climate calculations for all its building projects. *Beta* had set an internal target for carrying out 100 climate calculations over the next two years. *Delta* had started to carry out building climate declarations on several of its own building projects.

While all the companies employed climate specialists, the distribution of responsibilities for LCA-based climate calculations varied among the different companies. *Alpha* employed climate analysts in different regions that routinely carried out climate calculations, allowing a few of them to develop into climate experts who were deployed as specialist resources for projects with more advanced climate requirements. *Beta* opted for cost engineers to carry out climate calculations, with support from a small central staff of climate experts. *Gamma* developed a combination of both approaches, with cost engineers carrying out routine climate calculations and dedicated climate experts acting as support and specialist resources for projects with higher ambitions. Delta had recently expanded the environmental sustainability unit to carry out climate calculations.

All the studied companies used economic cost calculations as a basis for collecting the material quantity data used for the LCA-based climate calculations. This created a shared problem related to the completeness and accuracy of the results, as cost calculations were only partially based on material quantities. Incomplete material quantification of cost calculations resulted from extensive subcontracting practices. Although the larger building companies had significant internal resources, it remained customary practice to outsource substantial parts of the work in building projects to subcontractors – e.g. excavation and ground works – as well as to suppliers of prefabricated building elements – e.g. elements to a load-bearing system. In line with these outsourcing practices, building companies tended to collect material quantity data only for those parts of the building design that they constructed themselves. Outsourced parts of the building project were commonly reduced to economic estimations and direct price-agreements – i.e. without specified material quantity data.

Recognising these limitations, companies had started to take an interest in improving the data collection process of quantity-based resource data. From an LCA perspective, technical adjustments were needed in *Alpha* and *Beta* to export quantity data from the existing cost estimation software. Indicative of the data-handling skills that had to be developed, one company expressed explicitly to focus on developing an Excel-based macro to aggregate data of similar materials in building parts. Several companies expressed concrete ambitions to increase data coverage and use supplier-specific data and, to a lesser extent, to use BIM-based climate calculations and more real-time calculation results.

Having surveyed available LCA-based software tools, *Alpha*, *Beta* and *Delta* started using IVL's BM tool to carry out most LCA-based climate calculations. *Gamma* continued to use its internal climate calculation tool. One Click LCA was primarily used by the companies in projects where building environmental certification schemes required a whole-life cycle climate calculation (e.g. BREEAM). While climate calculations relied heavily on generic emission data for building products, a start was made by introducing EPDs to the calculations.

With *Alpha, Beta*, and *Delta* relying on the same LCA software, efforts in each of these companies independently were geared towards developing internal data processes in line with the opportunities and constraints of IVL's climate calculation tool. For example, to systematically match the imported resource data to environmental data, *Alpha* and *Beta* developed a 'resource library' within the software tool – linking resource codes from the cost estimation software to an equivalent building resource in the LCA software's emission database – while adding a conversion factor if necessary to match the standard units in both databases. By using a resource library with standardised couplings between resource data and emission data, companies could speed up the analysis process while reducing variability between building projects. The LCA specialists at these companies expressed ambitions to verify the quality of these resource libraries and a need to guard the company's shared codes against unique project-based codes or couplings. In doing so, the structure of IVL's BM tool influenced local cost calculation practices in building projects throughout the country.

4.2.2. LCA practices in the building projects (2021)

With experience accumulating, the studied organisations were increasingly orienting LCA-based climate calculations away from R&D applications and towards building projects. Whereas in 2017, only *Gamma* carried out climate calculations in the context of building projects, all the studied building companies did so by 2021. Nonetheless, at *Beta* and *Delta*, LCA use was still expressed as an indicator of a high-end sustainability project. In addition, building companies were experiencing that external clients – including project developers and housing associations – were starting to play an active role in demanding LCA-based climate calculations. While external clients in the studied projects did not yet set concrete climate targets, it became more common to demand that LCA-based climate calculations be carried out in projects.

Table 3 gives an overview of the LCA-based climate calculations carried out in the studied building projects. While the results reported in Table 3 are not intended to be compared, they do illustrate some variations in the LCA-based climate calculations. The project with the highest calculated upstream climate impact belonged to the *Gamma* building company, which had the most experience with LCA use in building projects. Notably, the *Gamma* project featured the most intensive LCA involvement in the projects studied, carried out the most complete LCA-based climate study, and had introduced the greatest number of improvement measures in the building design.

Results from the presented climate calculations are difficult to compare even where the building types are similar, as the system boundaries and resource data coverage differ between the studies, both horizontally and vertically, and because the environmental data sources differ between software programs. Furthermore, data coverage was typically reported as a proxy of the extent to which the LCA software coupled data to generic environmental data rather than the percentage of the whole building that was included in the study. Finally, some building LCA studies included generic sector-based values for data gaps without this being immediately visible in the reports (e.g. A4, A5).

None of the studies made comparative assertions to buildings developed by competing companies. Instead, a range of different internal comparative statements were made in the different reports, i.e. comparing results with generic-specific data, building improvements, and internal and external targets. Only *Gamma* appeared to have used a systematic approach in which building reference values had been specified for the company.

In 2021, data verification was still in its infancy. This was perceived to be problematic by several interviewees, as the quantity values from the cost calculation software were merely projections of the buildings that the companies were planning to build. Experienced LCA practitioners at *Alpha* and *Gamma* feared a systematic underrepresentation of LCA results by competing companies due to perceived lower LCA competences and due to a strategic incentive to underestimate material quantities in subcontracted building works. In contrast to cost estimations, which could be compared with actual costs paid during building construction, projected GWP values in a building project are not monitored against actual emissions or impacts. Hence, a verification of resource quantities and EPD data use was deemed necessary.

Importantly, one of the companies confided that prescribed cement levels of concrete in building designs of the company systematically underrepresented actual cement levels in concrete use during construction. The company discovered that most construction projects had been switching to higher cement-based concrete mixtures, reportedly to reduce drying times and meet project time schedules. In addition, incorrect resource data for concrete mixtures have been used in at least one high-profile Swedish building LCA study.

With the use of LCA-based climate calculations in building projects, opportunities emerged to orient LCA use towards actively reducing building life cycle climate impacts. For the time being, only the *Gamma* building project had used LCA to systematically address building environmental impacts. At *Alpha* and *Beta,* ex-post analyses were carried out to assess the effects of the improvement options already selected in the project – i.e. without the LCA work being a direct ground for such decisions. At *Alpha* and *Delta,* theoretical improvement options were considered as part of the scenario analyses. All the companies expressed the ambition to use LCA early in the building design process, which contrasts with the ex-post analyses that were commonly carried out and prescribed by the upcoming regulation on building climate declarations.

Although LCAs were oriented increasingly toward building projects, it remains ambiguous which substantive effects on building environmental performance have been achieved. A building project that carried an efficient design as a starting point or baseline could subsequently account for few additional design improvements, whereas a project that started analysing an inefficient design had more space for implementing design improvements. For example, *Delta* produced a wood-based building with a low climate impact but accounted for few climate improvements in its design, as climate impacts were not compared with those of a standard concrete-based alternative. For the building companies, the use of EPD data could be counted as a sustainability improvement in the building design even in situations where no switch in the supplier was made.

4.3. A more routine use of LCA-based climate calculations (2025)

At the beginning of 2025, it had been three years since the legal requirements for LCA-based climate declarations had entered into force for new building projects. Between 2022 and 2024, a total of 1765 building climate declarations were registered with the Swedish National Board of Housing, Building and Planning (Boverket), including 317 climate declarations for multifamily residential building projects. The median value for climate declarations of multifamily residential buildings was 203 kg CO2e per m2 gross floor area (Boverket, 2025), substantially lower than the Swedish reference value for multifamily residential buildings, which for 2022 was set at 298 kg CO2e per m2 gross floor area (Malmqvist et al., 2023).[1]

The sector was anticipating a tightening of the rules in the period up to 2030. Future requirements for building climate declarations are expected to (1.) expand system boundaries beyond building parts 2-6 (2.) expand system boundaries beyond life cycle modules A1-5 to include operational (B) and end-of-life stages (C), (3.) increase the proportion of building climate impacts covered by EPD data, and (4.) introduce legally binding reference values.

4.3.1. LCA practices in the building companies (2025)

By 2025, LCA-based climate practices had matured in the studied building companies. LCA-based climate declarations were carried out for all new building projects. The data collection practices of the studied building companies had become more standardised as a result of the methodological requirements introduced in the legislation for climate declarations. The legislation had set methodological requirements for the calculation and verification of climate declarations. With calculation rules and data practices in place, the act on climate declarations created methodological conditions that allowed building companies to carry out LCA studies routinely and systematically. Mostly, LCA-based calculations focused heavily on upstream climate impacts, aligning with the methodological standard for climate declarations.

At the same time, the companies continued to display different LCA-based practices despite a shared institutional framework. For example, *Delta* did not limit its building climate calculation to upstream parts of the building life cycle. In addition, all the studied companies continued to carry out LCA-based climate calculations that deviated from the methodological standard prescribed by Boverket. In particular, it was

[1] The environmental data on which climate declarations and the reference values were based differed, hindering a direct comparison of these values. Swedish reference values developed by Malmqvist et al. (2023) were based on average GWP values for building resources whereas the building climate declarations were based on a mixture of conservative values (adding 25% to typical values) and EPDs.

Table 3
LCA-based climate calculations and improvement measures in building projects (2021).

Building project	Alpha21	Beta21	Gamma21	Delta21(a)	Delta21(b)
Location	North Sweden	South Sweden	West Sweden	South Sweden	South Sweden
Year completed	2022	2023	2022	2022	2021
Building type	Multi-family house	Multi-family house	Multi-family house, special	Multi-family house	Logistics, special
Load bearing system	Concrete, cast on site	Concrete, mix	Concrete, prefab	Cross-laminated timber	Concrete, steel pillar
Gross floor area (m2)	3000	10 000	5000	6000	11 000
Building commissioner	External	Internal	Internal	External	External
LCA-based target	None	None	Internal	None	None
LCA study					
Goal study	Accounting	Learning	Improvement	Learning	Learning
Functional unit	1m2 GFA	1m2 GFA	1m2 GFA	1m2 GFA	1m2 GFA
LC modules (EN15978)	A1-A5.1	A1-A5.1	A1-B7	A1-A5.1	A1-A5.1
Building parts (BSAB83)	2-6	2-8	0-9	2-8	2-6
Impact categories	GWP (GHG)	GWP (GHG)	GWP (GHG)	GWP (GHG)	GWP (GHG)
Source resource data	Cost projections	Cost projections	Cost projections	Cost projections	Cost projections
EPD (% total GWP values)	50%	41%	Unclear	18%	25%
Scenario analyses	Improvements	Data use	Mixed	Data use	Data use
Calculated change in scenario (A1-5)	−26%	−5%	−16%	−8%	−21%
Results kg CO2e/m2 Gross Floor Area (GFA)					
A1-3 Product stage	172	323	348	143	250
A4 Transport	10	21	29	15	19
A5.1 Construct. waste	9	10	6	5	15
Total A1-5.1	191	353	382	163	284
Identified improvement measures A1-5					
	• Climate improved concrete • Exchange to mortar with EPD	• Climate improved concrete • Climate improved reinforcing steel • Transport, renewable fuels	• Reduce height entrance floor • Exchange brick for concrete facade • Local supplier structural elements • Climate improved reinforcing steel • Climate improved concrete in ground slab • Exchange insulation material underground slab • Exchange insulation material to glass wool • Exchange LECA for foam-glass • Optimise piling • Optimise foundation • Renewable fuel for excavation machines • Certified district heating on site	• Cross laminated timber (CLT), load bearing system • Climate improved concrete • Optimise transport • Climate improved reinforcing steel	-

common practice to adjust system boundaries and calculation principles to align with the instrumental purpose of LCA for the building project, the client, and other involved actors.

To accommodate the increasing volume and variety of LCA-based practices, the organisation of LCA work had evolved in the studied companies. At *Alpha,* climate calculations continued to be performed by climate analysts but had expanded the role of construction engineers. At *Beta and Gamma,* the routine was inverse, and cost engineers were carrying out most of the routine climate calculations, with additional support from climate specialists. In these companies, several climate analysts had become climate specialists, focusing on expert-driven support for projects and strategic work for the company. This process of specialisation was best visible at *Gamma*. Compared with 2021, routine LCA work was carried out more often by cost engineers. The role of LCA specialists had evolved to support high-end projects.

At *Alpha,* climate specialists continued to carry out most climate calculations, with a few becoming increasingly involved in company strategic questions. At *Beta,* climate specialists had started to systematically gather information on climate calculations across building projects to be used for strategic company-wide purposes. In building projects, climate specialists were frequently involved in projects with higher ambitions regarding climate work. The situation at *Delta* was slightly different, as building climate calculations were no longer carried out internally but were outsourced to an external consultancy company specialising in climate calculations. Consequently, outsourcing climate calculations shifted the role of the LCA analysts towards a coordinative role.

With an increasing diversity of possible LCA practices, all companies had developed internal working documents that describe how to work with climate calculations in building projects. The working documents carried requirements about when to carry out additional climate calculations, descriptions of how different LCA practices could look like in building projects to obtain different goals, and descriptions of how building projects could contribute to company-wide climate targets. The development of internal climate targets for building projects was perceived to be increasingly relevant in connection with an anticipated introduction of limit values for building climate impacts.

All the studied companies had developed internal strategy documents containing target values for the expected GWP values of new building projects. While the level of implementation differed between the companies, the orientations of these strategy documents were similar. As a historic front runner, *Gamma* had formally integrated internal LCA-based targets into its building projects. At *Beta*, the production organisation had implemented an internal demand for carrying out climate calculations during the procurement phase, while the other measures were still pending. Uncertainty as to the exact introduction of limit values in the sector in combination with more difficult market conditions was perceived to slow down the implementation of these strategy documents. At *Delta*, a recently developed internal strategy document was pending for approval of the company's senior management.

With respect to LCA software use, IVL's BM climate tool continued to take a prominent place in climate calculation practices for *Alpha* and *Beta.* Most analysts perceived the climate tool to be functional and well aligned with the requirements for climate declarations. *Delta* had switched to outsourcing building climate declarations to a company called *Plant,* which carried out LCA-based climate calculations and declarations supported by BIM data. Other companies had started using additional climate calculation tools in different LCA-based practices. For example, *Alpha* had started using NODON, a parametric building climate tool to be used in the planning stages of a building project. OneClick LCA remained primarily used for building environmental certification schemes requiring full life cycle climate calculations. Some experiences with plug-in climate calculation tools in cost calculation software were reported by *Beta* and *Delta.* In addition, *Gamma* continued to develop the integration of their climate calculation and cost calculation software to support rapid climate calculations in its building projects.

4.3.2. LCA practices in the building projects (2025)

By 2025, LCA-based climate calculations had become firmly established in the studied building projects, and the mere use of LCA was no longer considered a sign of a high-end sustainability project. All the studied projects had oriented LCA-based practices towards reducing building climate impacts to meet demands from internal or external clients. At *Alpha, the* GWP values formed a competitive element in the tender process of the studied project. At *Beta*, a climate target was agreed upon in dialogue with the external client. At *Gamma,* an internal project climate target was set on the basis of the year of inception of the studied project. At *Delta,* the external client required a percentage-based reduction in GWP values.

Setting environmental targets in building projects stimulated a different use of LCA-based climate calculations. In addition to ex post climate calculations, the building projects with environmental targets all carried out climate calculations at the beginning of the projects, or at least when the contractor became involved. To ensure that the climate targets agreed upon were achievable within the projects, climate specialists were more actively involved in these early calculations. Additionally, LCA-based climate practices were used to build relationships with external clients in the studied building projects.

Carrying out early-project climate calculations focused heavily on generic building resource data, as the building design had not yet been fully specified and because suppliers of building products and materials were not always known. The limited availability of supplier-specific data during early design stages put pressure on the accuracy of these climate calculations.

The studied building projects typically attempted to obtain as much supplier-specific data as possible relatively early in a project, at least for key building products and materials. At *Beta,* the choice for a small concrete element supplier involved contractual negotiations that stipulated a maximum climate impact for the elements. Here, interest in controlling the economic costs and expected climate impacts of a building project aligned with each other. Although the supplier did not have a ready-made EPD for the concrete building elements that were purchased, the long lead-times between agreeing on a purchase and product delivery to the construction site allowed the material supplier to develop the EPDs in time.

The use of LCA-based climate calculations proceeded differently in the projects. At *Beta*, the use of climate calculations was restricted to the beginning and end of the building project. With sufficient confidence that the contractual agreed-upon environmental target could be met, there was no desire to carry out additional LCA calculations. In contrast, *Alpha* and *Gamma* carried out climate calculations during each project stage to support a more continuous drive for finding additional climate improvements in the building project. At *Alpha* and *Gamma*, integrated LCA use was supported by internal work documents describing the work process. Typically, it involved a heavier upfront involvement of an LCA specialist with the building project to determine the direction of the project, followed by regular meetings to discuss improvements made throughout the project. A full-scale integration of LCA use in the building project was deemed resource intensive and needed to be justified.

From an environmental perspective, an integrated use of LCA in building projects added LCA-based competence and resources to the project that could be used to support design and construction practices and reduce a project's climate impacts. This process was most visible at *Gamma,* where a continuous engagement of the climate specialist in the design and construction process supported the development and implementation of several novel climate improvements in two consecutive building projects (see Table 4). At *Alpha,* a list of ten product categories with the largest climate impact was used as a start for structuring the search for improvement options during the building project. In contrast, at *Beta,* sustainability improvements in the concrete structure of the building project were agreed upon before the contractor took on the project and were stipulated in the contract with the concrete element supplier. At *Delta*, the LCA consultancy company presented the contractor with suggestions for reducing building environmental impacts that could be shared with the client.

Notwithstanding the importance of climate specialists for managing LCA processes, reducing product environmental performance through substantive improvements was typically an interactive process. The adoption of climate improvements in the projects studied at *Alpha, Beta* and *Gamma* involved close interactions among LCA specialists, project leaders, technical engineers, and clients. Here, climate work aligned itself with the design process in building projects. New climate improvements were typically derived from brainstorming sessions or from the personal knowledge of project- and site-managers. The primary role of the climate specialist in these meetings was to guide the discussions and share expertise from other projects.

From an economic perspective, adopted climate improvement measures were frequently considered to be cost neutral. If needed to reach a set climate target, additional improvement measures were selected on the basis of a positive cost−benefit ratio in the studied building projects. New climate improvements developed in the studied building projects were to varying degrees formalised in the building companies. At *Alpha* and *Gamma*, climate specialists described having developed personal experience from earlier building projects into lists that systematise sustainability improvements across projects, allowing for a formalisation of expertise. Ultimately, design or building improvement could become included in the document that prescribes a company's standard technical solutions. However, such improvements were difficult to trace back to climate work in individual projects. Instead, projects could serve as a test bed for working with production methods that were novel from the company perspective, relating individual projects to more continuous innovation processes in a company.

Many improvement options focused on the exchange of individual materials or products of suppliers to obtain the products where the lowest EPD value could be obtained. Furthermore, optimising the use of concrete and using climate-improved concrete were commonly used improvement solutions. Despite a perceived negative effect on the drying time of concrete, these climate improvements were relatively easy to implement, as they did not require substantial changes in the building design or building process. These improvement options were also identified as 'low-hanging fruits'. Wood-based load-bearing systems had been discarded in numerous projects, accordingly because of excessive economic costs.

From a climate perspective, there was not always a straightforward relationship between the quantity and quality of climate improvements accounted for in the project and the final LCA results. In particular, the

Table 4
LCA-based climate calculations and improvement measures in building projects (2025).

Building project	Alpha25	Beta25	Gamma25	Delta25
Location	South Sweden	West Sweden	West Sweden	West Sweden
Year completed	2023	2025	2025	2024
Building type	Multi-family + terraced house	Multi-family house	Multi-family house	Logistics
Load bearing system	Concrete, case on site	Concrete, prefab	Concrete, mix	Concrete, steel
Gross floor area (m2)	9000	8000	11 000	31 000
Building commissioner	External	External	Internal	External
LCA-based target	Tender	Contractual	Internal	Contractual
LCA study				
Goal study	Mixed	Mixed	Mixed	Mixed
Functional unit	1m2 GFA	1m2 GFA	1m2 GFA	1m2 GFA
LC modules (EN15978)	A1-5.2	A1-5	A1-5	A1-C4
Building parts (BSAB83)	2-6	2-7	0-9	2-8
Impact categories	GWP (GHG)	GWP (GHG)	GWP (GHG)	GWP (GHG)
Source resource data	Cost projections	Cost projections	Cost projections	BIM model
EPD (% total GWP values)	87%	62%	21%	76%
Scenario analyses	Mixed, other project	Mixed	Mixed	Mixed
Calculated change in scenario	−39%	−13%	−35%	−24%
Results kg CO2e/m2 Gross Floor Area (GFA)				
A1-3 Product	171	186	148	153
A4 Transport	6	35	15	11
A5.1 Construction waste	6	3	6	13
Total A1-5.1	184	224	169	177
Identified improvement measures A1-5				
	• Reduce concrete use • Slimmer load bearing structures • Optimise strength class concrete • Climate improved concrete • Exchange brick type • Exchange roofing material to bitumen • Exchange metal studs to wooden studs • Reduce waste reinforcing steel • Renewable energy on site • Reuse concrete waste • Flexible time plan	• Climate improved concrete • Wood-based curtain walls • Wooden façade • Supplier reinforcing steel with EPD	• Wood-based curtain walls • Reduce reinforcing steel • Optimise piling method and quantity • Exchange brick type • Paper-based studs certain inner walls • Exchange glass wool for cellulose insulation • Reduce slab stair well and landing • Supplier reinforcing steel with EPD • Reduce reinforcing in piles • Climate improved concrete	• Climate improved concrete • Steel structure with EPD • Minor material choices with EPD • Renewable fuel and district heating on site

climate impacts of a building project are influenced by the starting conditions of the project. At *Alpha,* project requirements related to municipal planning and site conditions led to a worse form factor, additional foundational works, and an underground garage that was absent from an earlier project carried out with the same client. Despite several additional climate improvements during the project, *Alpha* could not overcome the additional climate impacts caused by what were perceived to be disadvantageous starting conditions.

Furthermore, the calculated climate impacts were substantially influenced by the availability and usage of EPD data. In all projects, EPD data – often containing lower values than generic environmental data – stimulated the early involvement of LCA analysts with purchasing questions. The methodological standard for climate declarations aims to stimulate the use of EPDs by adding a 25% penalty to the usage of generic climate data. However, in the absence of legal limit values, this penalty carried little weight. Practically, climate calculations in the building projects deviated from the methodological standard by using typical values rather than conservative generic values. Hence, using typical values allowed building projects to present lower – and presumably more accurate – results for climate impact. Subsequently, it created two versions of LCA-based climate results in building projects – one for internal use and communication to the client and one for compliance with the legal requirements.

5. Discussion

A longitudinal episodic cross-case account of building-specific LCA practices within four Swedish building companies between 2017 and 2025 has been presented. Taking a nested approach, the cases addressed LCA-based practices in temporally bounded building projects and related these to more continuous and shared practices within the company. The cross-case account enabled to examine how building companies developed their LCA practices during a period in which a legal requirement for LCA-based climate declarations was introduced for new building projects (RQ1), and to understand how the introduction of a regulatory methodological standard reshaped the variety and characteristics of LCA-based practices in the studied building companies (RQ2).

5.1. Development of building-specific LCA practices between 2017 and 2025

The studied cases showed a remarkable increase in the volume and variety of building-specific LCA practices between 2017 and 2025 (see Table 5). In 2017, there were few LCA-based practices. Of the four companies studied, only one routinely carried out LCA-based climate calculations. The other three companies showed interest in learning about building LCA but were still developing the internal capacity to carry out LCA-based climate calculations. By 2025, LCA-based practices had developed to become part of the everyday routine in the building

Table 5
Overview of the development of LCA-based practices in the studied cases between 2017 and 2025.

	2017	2021	2025
Status legislation	- Intention to introduce building climate declarations	- Methodological standard for building climate declarations is available for use	- Legislation on building climate declarations is in effect (since 1 January 2022)
LCA-based climate calculations in studied cases	- No assessments (B, Δ) - A few assessments in R&D projects (A) - Assessments on internally developed building projects (Γ)	- Assessments on several projects (Δ) - Assessments on many building projects (A, B) - Assessments on internal projects and projects with climate ambitions (Γ)	- Climate declarations are a legal requirement - Climate goal in tender phase of projects with climate ambitions (Δ) - Assessments in tender phase of internal projects and projects with climate ambitions (B) - Assessments in four projects phases in internal projects and projects with climate ambitions (A, Γ)

Uses in LCA-based practices in studied cases	- Research and development
	- Learning
	  - LCA method
	  - software use
	  - data collection
	  - climate hotspots
		- Research and development
		- Learning
		  - climate hotspots
		  - climate declarations
		  - climate optimisation
		- Climate optimisation in projects (novel)
		- Environmental certification schemes
		- Company strategies and targets (Γ)
			- Research and development
			- Learning
			  - climate optimisation
			  - climate targets
			  - project relations
			- Climate optimisation in projects (routine)
			- Environmental certification schemes
			- Climate declarations in permit process
			- Procurement
			- Purchasing
			- Company strategies and targets

Effects on studied cases	- None	- LCA practices reduce building climate impacts (Γ) - LCT reduces building climate impacts, with ex-post LCA to confirm (A, B, Δ)	- LCA practices reduce building climate impacts - LCA practices shape relations with suppliers and clients through purchasing and procurement

Note: Companies and projects are denoted as follows - Alpha (A), Beta (B), Gamma (Γ), and Delta (Δ). If unspecified, the outcomes are visible at all studied companies and projects (i.e. A, B, Γ, and Δ).

companies, playing an integral part in the studied building projects. The growth in the volume of LCA-based activities is also illustrated by data from the National Board of Housing, Building and Planning (*Boverket*). In a sector where most companies were struggling to produce any LCA-based climate calculations in 2017, *Boverket* registered 1041 building climate declarations in 2024 alone (Boverket, 2025).

In addition to a growing volume, the results also revealed that a variety of building-specific LCA practices had developed. In 2017, building-specific LCA practices were limited to R&D and used to learn about the method and building climate hotspots. By 2025, a wide pallet of building-specific LCA practices had developed integrating LCA-based climate calculations with sustainable building practices in projects operations and company strategising (see Table 5). In line with these developments, learning about LCA had evolved from being primarily knowledge oriented toward becoming effect oriented – i.e. focused on using the method to shape project relations and effectively reduce building climate impacts. LCA-based calculations were connected to sustainable building practices through (1) R&D and learning (2) climate optimisation within building projects, (3) building environmental certifications (4) climate declarations in the permit process (5) procurement processes, (6) purchasing processes, and (7) company strategies and targets.

The evidence presented in this longitudinal study shows how LCA-based practices are integrated within building projects, reshaping sustainable building practices with the aim of reducing building climate impacts. These findings strongly contrast with research claims that LCA is not effectively used in project workflows to reduce building climate impacts (e.g. McCord et al., 2024; Somerset et al., 2025). Whereas the studied building companies may indeed have started by developing LCA-based practices outside a project-context, over the course of the studied period the LCA-based practices had evolved to become an integral part of project workflows and sustainable building practices.

The development of different uses for LCA in sustainable building practices also contrasts with the findings of Kastner et al. (2025), who found on the basis of corporate environmental reports of five large Japanese construction companies that LCT adoption did not evolve in practice, despite observing an increasing volume over time. The evidence presented in our study shows that LCA practices can reshape both internal project dynamics and external market dynamics. In particular, the adoption of LCA-based targets and EPD use stimulated a dynamic in which suppliers, subcontractors, and clients were increasingly involved in creating more sustainable building practices. These findings contrast with those of Testa et al. (2011), who considered other information-based instruments – EMS – to be ineffective at stimulating environmental innovation. A possible reason for these contrasting findings is that the product life cycle orientation of LCA is more directly useful for building projects than the company-oriented focus of EMS was at the time (c.f. Gluch and Räisänen, 2012).

To see LCA use evolve towards effectively reshaping building practices in projects and companies is an important contribution of the present study. LCA and climate calculation practices were usefully adapted following the interactions related to planning, design, and construction processes, including relationships with clients and suppliers. These findings confirm the relevance of interaction processes observed in the LCA and LCM literature (Heiskanen, 2002; Nilsson-Lindén et al., 2019) and support the notion that the effects of LCA use do not follow linearly from the outcomes of an LCA study but rather follow a complex sequence of events involving a variety of LCA-based knowledge, activities, and practices (Beemsterboer et al., 2025).

Analytically, the development of building-specific LCA practices followed an institutional trajectory in the studied companies that has been observed previously in other domains as well (Baumann, 1998; Frankl and Rubik, 2000). The empirical findings suggest that *Alpha, Beta, and Delta* have progressed from a *habitualisation phase* down to a *sedimentation phase* between 2017 and 2025. As an early adopter, *Gamma* started with a more advanced understanding of LCA and could develop quicker towards more advanced institutional phases. Although the speed with which LCA-based practices developed within the building companies differed in line with existing ambitions and capabilities, the results indicate that all organisations developed along a similar institutional trajectory toward more integrated LCA-based practices.

The case studies provided evidence of the presence of several institutional elements associated with the *sedimentation phase* (Baumann, 1998; Frankl and Rubik, 2000). First, a formal LCA structure was in place in all four companies. Although the degree of implementation differed between the companies, all the case companies developed strategy and operational documents that codified corporate and project-level climate targets and communicated how to operationalise LCA in projects. Similarly, different organisational structures around LCA work had been developed to ensure that LCA-based practices could continue when individual LCA analysts or specialists left the company. Second, the companies provided evidence of more diverse uses of LCA. Importantly, LCA-based practices were also expanding from focusing primarily on climate calculations to becoming more integrated in project work and effectively reducing building environmental impacts. While most companies had landed on a preferred LCA software and aligned their own data collection processes accordingly, there was also evidence of experimentation with alternative software programs for different purposes. Finally, carrying out LCA-based climate calculations required less expertise. LCA calculations were increasingly conducted by cost engineers (*Beta, Gamma*) or outsourced to external consultants (*Delta*), whereas the available LCA expertise was instead reserved for LCA-based practices oriented toward more advanced project or company goals.

In addition, the development of LCA-based practices in the studied companies resembled an organisational learning pathway suggested by Tessitore et al. (2025). First, the companies learned to *draw on LCA* by making GWP a selection criterion, integrating environmental sustainability in the design stage, and strengthening eco-innovation processes. Most commonly, LCA was used in projects that reduced building environmental performance by optimising concrete use, introducing wood-based building elements or components, exchanging building products and materials, exchanging suppliers, reducing waste, optimising transport, and using renewable energy sources on site. In addition, LCA was used in connection to structural design changes, reducing the total material quantities needed – e.g. lowering the entry-floor level, optimising the piling, or the thickness of particular building elements.

Second, LCA-based practices were seen to *trigger a process of identity change* among certain professionals. For example, the role of cost-engineers has changed in several companies to accommodate the material quantity lists that underlie LCA-based climate calculations. In addition, LCA was used to consolidate the corporate environmental image through communicated targets and showcases. Perhaps most importantly, LCA-based practices helped to develop a collaborative approach to sustainability with project actors. Third, there was evidence of *reshuffling organisational tasks* by integrating LCA more actively in building projects, into contacts and contracts with clients, and expanding work roles. Finally, the case studies provide evidence of *reconfiguring* business strategies. Climate targets were becoming more important in the studied companies. The projects provided evidence that the ability to meet carbon targets was becoming increasingly relevant to clients and was interpreted by several interviewed building practitioners as a precondition to win future contracts. In doing so, the research findings supported the elements of the organisational learning pathway identified by Tessitore et al. (2025).

Alignment with institutional patterns presented in Baumann (1998), Frankl and Rubik (2000), and Tessitore et al. (2025) shows a growing institutional maturity of LCA-based practices at the studied organisations. By developing organisational structures surrounding LCA-based practices, building companies can carry a growing volume and variety of LCA practices effectively. That even *Delta* continued to develop LCA-oriented organisational structures, while outsourcing large parts of the LCA work, is a clear sign that the organisation of LCA practices is becoming increasingly relevant. Given the growing regulatory- and market-driven demands for LCA, it can be expected that companies will continue to develop internal institutions for supporting LCA-based practices. To better understand how LCA is used effectively, future research is therefore recommended to study the organisation of LCA practices in companies more explicitly.

5.2. Influence of a regulatory methodological standard on LCA-based practices

The research revealed increases in the volume and variety of building-specific LCA practices during the period in which the legislation for building climate declarations was introduced, accompanied by a growing institutional maturity at the studied building companies. The complexity of regulatory- and market-driven developments in the built environment limit the ability to establish a formal causal effect from the building climate declarations specifically. Within these limitations, the legislation on building climate declarations was nonetheless understood to have stimulated building-specific LCA practices by creating organisational resources and a clear mandate for LCA in building projects.

More importantly, the increasing variety in building-specific LCA practices is evidence that the implementation of building climate declarations did not constrain LCA-based practices in the studied cases. Carrying multiple LCA-based practices enabled actors to comply with the legislative requirements for building climate declarations while simultaneously being useful for other purposes in building projects. These findings present a more positive image of the influence of regulatory methodological standards, contrasting with evidence of a compliance-based LCA culture presented in studies at biofuel companies (Lazarevic and Martin, 2018) and the Danish building sector (Somerset et al., 2025).

The findings further highlight the complexity of practical and organisational responses to institutional pressures, as suggested in the literature (Giddens, 1984; Hoffman and Ventresca, 2002; Milstein et al., 2002). Previously, Daddi et al. (2016) reported that coercive pressures tend to contribute to ceremonial and compliance-based EMS adoption, highlighting the importance of voluntary mechanisms for the effective adoption of this information-based instrument. Rather than contrasting coercive pressures with voluntary institutional pressures, the research findings suggest that they may co-exist and complement each other.

The results of our study clarify that institutional pressure exerted by LCA-oriented legislation does not have to conflict with an effective use of LCA in building projects when actors are able to carry multiple LCA-based practices in parallel. In the studied cases, many of these parallel LCA practices deviated from the methodological standard of building climate declarations by introducing different functional units, system boundaries, data sources, or impact assessment categories (see Table 6). While deviations from a common methodological standard have typically been viewed negatively – i.e. introducing subjectivity (De Wolf et al., 2017), the results from our research suggest that this is too limited a view.

Where LCA practices are expected to reduce product environmental

Table 6
LCA practices deviating from the methodological standard of building climate declarations.

	Building climate declarations	“Deviating” LCA practices
Orientation	- Legislative compliance - External use	- Market-orientation - Internal and external use
Functional unit	- 1 m2 GFA/50y	- 1 m2 HFA/50y - Building unit/50y - 1 m2 GFA/100 y
System boundaries	- A1-5 - Climate shell, load bearing system, inner walls	- A1-3, A1-3 & B6, A1-5 & B6, A1-C4 - Excluding and including other building elements
Life cycle inventory (LCI)	- Verified primary building quantity data - Conservative GWP values from national climate database for construction materials (+25%) - Primary EPD data	- Unverified primary building quantity data - Secondary building quantity data – other projects, average data & projections - Typical GWP values from national climate database for construction materials - Secondary EPD data, hands-on calculations
Life cycle impact assessment (LCIA)	- GWP-GHG	- GWP-Total - Other impact categories

impacts, deviations from a methodological standard can play an instrumental role in alligning LCA with different practical concerns in the application context – i.e. purposes, uses, practices, and institutional logics. In the studied cases, building-specific LCA practices were alligned with legitimate practical concerns for sustainable building – i.e. environmental certification schemes, local climate schemes, client demands, climate optimisation tools, previously carried out climate calculations, and company internal targets. While some of these practical concerns were formalised in methodological standards themselves others were ad-hoc and connected to individual building projects.

The results of this study imply that deviations from a methodological standard can be positive, when they allow LCA practices to develop and allign themselves with legitimate practical concerns in sustainable building. The practice of alligning environmental knowledge with other purposes and institutional logics is supported by existing empirical research on LCA and LCM practices (Heiskanen, 2002; Nilsson-Lindén et al., 2019) as well as by studies of environmental work in building (Gluch and Hellsvik, 2023). Theoretically, these adjustment processes are expressions of a pragmatic approach to LCA (Beemsterboer, 2025). While methodological standards are important for supporting the credibilty of LCA and building climate declarations, it is useful to be attentive to how legitimate practical concerns shape the application of these methods, and how actors use LCA to move beyond compliance and support more sustainable building practices.

6. Conclusions

This article presents insights from a longitudinal episodic study about building-specific LCA practices within four Swedish building companies. To better understand the influence of legislation-driven LCA on existing LCA practices, this study examined the evolution of building-specific LCA practices between 2017 and 2025. The studied period was especially relevant because it included the development and implementation of a legal requirement for LCA-based climate declarations in new building projects in Sweden.

The research findings revealed a strong increase in the volume and variety of building-specific LCA practices in the studied cases. Although LCA was initially an R&D-oriented method for assessing building climate hotspots, it evolved to become a routine practice in building projects by 2025. LCA-based climate calculations were increasingly integrated into the studied building projects to reduce building climate impacts. During this period, all companies had developed a relatively mature institutional structure surrounding building-specific LCA practices. The study finds that LCA-oriented legislation can stimulate building-specific LCA practices by creating organisational resources and a clear mandate for LCA in projects. Evidence of a negative influence on LCA-based practices is currently low in the studied cases precisely because of the ability to carry multiple LCA-based practices in parallel.

The results show how organisations act in response to legislative institutional pressure, avoiding a compliance-based culture by adjusting building-specific LCA practices to competing practical concerns in building projects and companies. The value of these deviating LCA practices for sustainable building implies that caution is advised when developing novel LCA-oriented legislation. Because legislation exerts a coercive power to practice LCA according to a standardised purpose and methodology, it may contribute to the development of a compliance-based LCA culture in targeted organisations. To avoid unintended negative effects on sustainable building practices, it is important for LCA-oriented legislation not to stifle the capacity of organisations to align LCA use with other legitimate concerns in building projects and companies.

Organisations that are unable to carry multiple LCA-based practices in response to legislative requirements will likely be at a competitive disadvantage in meeting climate demands from both governing authorities and market actors. The risk of developing a compliance-based LCA culture is especially pertinent to small and medium-sized enterprises (SMEs) as they tend to have fewer organisational resources to practice LCA. Given the current growth in LCA-oriented legislation across countries and sectors, researchers and legislators are recommended to pay closer attention to the effects of legal requirements on existing LCA-based practices in affected organisations.

CRediT authorship contribution statement

Sjouke Beemsterboer: Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Writing – original draft, Writing – review & editing. **Henrikke Baumann:** Supervision, Writing – review & editing. **Holger Wallbaum:** Funding acquisition, Supervision, Writing – review & editing.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Sjouke Beemsterboer reports financial support was provided by The Development Fund of the Swedish Construction Industry (SBUF) (#13292; #13839). Holger Wallbaum is subject-editor in DIBE. Given his role as subject editor, HW had no involvement in the peer review of this article and had no access to information regarding its peer review. Full responsibility for the editorial process for this article was delegated to another journal editor. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The authors confirm that the data supporting the findings of this study are available within the article. Additionally, restrictions apply to the interview data, which are confidential.

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