SASBE 2025 aims to encourage the international exchange of innovative ideas between researchers from academia and industry. In addition to knowledge dissemination, the conference offers a valuable platform for professional networking, particularly benefiting university professors, graduate students, and postdoctoral researchers.

Research Article

Towards Socially Sound Sustainable Building Projects with a Novel Life Cycle Assessment Method

Anna Elisabeth Kristoffersen[1], Ted Kesik[2], Carl Schultz[3], Aliakbar Kamari[1]

[1] Department of Civil and Architectural Engineering, Aarhus University, Aarhus, Denmark
[2] Daniels Faculty of Architecture, Landscape and Design, University of Toronto, Toronto, Canada
[3] Department of Electrical and Computer Engineering, Aarhus University, Aarhus, Denmark
Correspondence: aek@cae.au.dk

Abstract

In architectural practice, social values are created through design choices made by architects. Integrating social intents, along with their corresponding design choices, into a design project has significant implications for the environmental impact of the building. This fac-tor is often inadequately addressed.

This paper presents an initial study towards adopting a novel environmental life cycle assessment (eLCA) approach for assessing the environmental impact of social intents in building projects. The study focuses on exploring eLCA's goal and scope setting through a robust methodological triangulation approach where the goal and scope are explored through various sources as follows: (a) a literature re-view of existing approaches within the building and construction industry, (b) narrative interviews and analysis with practicing architects, and finally (c) through a practical investigation carried out on social design intents from actual building projects.

The preliminary findings indicate that incorporating social intentions into building projects yields significantly varying effects on the emissions of the building, contingent upon the specific design choices that facilitate these social intents. Furthermore, the findings underscore the necessity for additional research to reconcile the functional unit with the established units from other eLCA methodologies. Such an alignment is crucial for enabling a comprehensive evaluation of the impact magnitude of social intents within the entire building context.

This work contributes to bridging the existing gap in the assessment of quantifiable environmental impacts versus qualitative intention-based social impacts, paving the way for more informed decision-making and socially sound, sustainable buildings.

Keywords: Life Cycle Assessment; LCA; Sustainable Buildings; Social Values; Social Intents; Design Choice; Environmental Sustainability; Decision-support

Highlights

- Social intents shape building design, but their environmental impact remains unexplored.
- Methodological triangulation is used, proposing a functional unit in eLCA of social intents.
- eLCA goal and scope setting can be aligned with the existing eLCA methodologies except for functional unit.
- A functional unit per social intents for quantifying the environmental impacts of social intents is proposed.

1 Introduction

The approach to sustainability in the building and construction industry is largely influenced by the concept of sustainability being composed of three pillars: social, environmental, and economic sustainability (Zimmermann et al., 2019). The sustainability of a building is assessed based on the fulfilment of system-specific criteria to a predefined level, at which the individual systems see the building as sustainable (Kristoffersen et al., 2023). This approach to the assessment can lead to a fragmented evaluation of a building's sustainability, as the checklist-like approach applied in the certification systems risks overlooking trade-offs and impacts of choices across multiple aspects of sustainability, thereby failing to encompass sustainability as a multifaceted and absolute concept.

The assessment of a building's sustainability is further complicated by social sustainability being described as "a concept in chaos" by Vallance et al. (2011) due to a lack of a commonly accepted definition or approach. In the years since this statement was first published, the clarification of the concept has not progressed significantly, as shown by Kristoffersen et al. (2024). This conceptual ambiguity associated with the terms social sustainability poses significant challenges for the practical implementation of the concept. Further adding to the challenge is the checklist-like approach from the building sustainability certification systems, where the list of criteria related to social sustainability encompasses themes such as thermal comfort, indoor air quality, and light access(Kristoffersen et al., 2023; Kristoffersen et al., 2024). Both sacrifice the broader, multifaceted perspective of social sustainability in favour of trying to operationalise it through isolated and measurable outcomes, while also ignoring or minimising the focus on environmental and economic impacts of the choices made to optimise criteria related to social sustainability.

Due to this ambiguity related to the term social sustainability, this paper builds upon the terminology proposed by Kristoffersen et al. (2024), focusing on the concept of social values (e.g., forming communities, engagement, identity, and well-being). This approach views social values as insufficient for ensuring social sustainability on their own. However, their inclusion can contribute to broader social sustainability, while also recognising that the inclusion of specific social intents alone cannot guarantee the social sustainability of a building, project, or community.

1.1 Social values in building projects

Buildings are created, designed and built for a variety of reasons. In its most basic form, the goal of a building is to fulfil its users' needs for shelter, safety, and a liveable environment, thereby contributing to the fulfilment of some of humanity's most basic needs to sustain life. The function and purpose of buildings extend beyond these basic functions to also form functional spaces and create varying values (Biskjaer et al., 2019). These values can, in the eyes of the user, be social values. Although social values may occur organically in a building due to how users behave, act, and use the building, other social values are introduced by building design stakeholders (e.g., architects) as they intend or wish for the building to impact its users. These intentions for creating social values (here: social intents) are rooted in architecturally oriented choices that impact the architecture and design of the building (here: design choices) (Entwistle & Rasmussen, 2022). Through this approach, buildings and the architectural choices made in the design become facilitators of social values through the incorporation of the social intents and their corresponding design choices. By leveraging social intents in the design phases, building design stakeholders can communicate a vision for how the finished building will impact its users. These visions and social intents lead project teams to make decisions regarding the design and architectural aspects of the building, which can significantly impact the building's overall environmental impact.

1.2 Aim and research question

To address the challenges of aspects related to each of the pillars of sustainability being assessed independently, this paper presents the first steps towards developing a methodology for assessing the environmental impacts of social initiatives. This is a step towards making it possible to, in parallel, discuss both the social and environmental impacts of a design choice. The aim of this study is therefore to answer the following research question:

- What scope (including system boundary and functional unit) should be applied in an eLCA when assessing the environmental impact of social intents?

In answering the presented research question, the study will apply mixed methods, triangulating the results based on semi-structured interviews, a literature review and a practical investigation through case studies. The research and paper structure follows the structure presented in Figure 1, the applied methodology in the triangulation is further described in the following section.

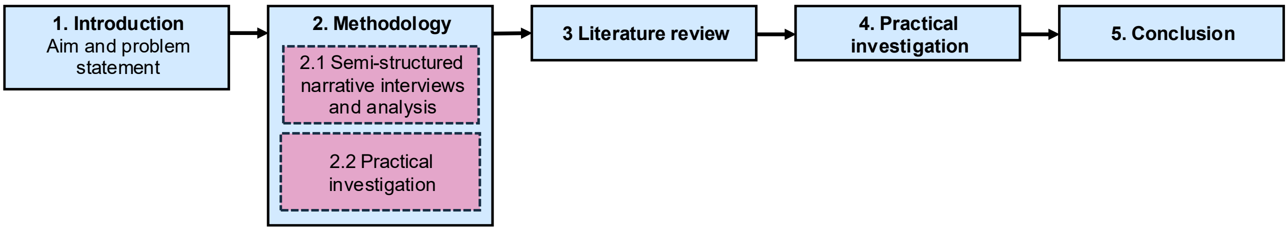


Figure 1. Overview of the research structure followed in the paper. The numbers in the figure refer to the section numbers throughout the paper.

2 Methodology

This study applies a methodological triangulation (Love et al., 2002). This approach allows for the exploration of a phenomenon through the application of multiple methods to limit the risk of biases and ensure the validity of results, thereby ensuring the robustness of the study and the findings. The three methodologies applied in the triangulation are a literature review, semi-structured narrative interviews and analysis, and a practical investigation, illustrated in Figure 2. The literature review in the study examines the existing approaches and practices regarding the goal and scope for environmental life cycle assessment (eLCA) in the building and construction industry.

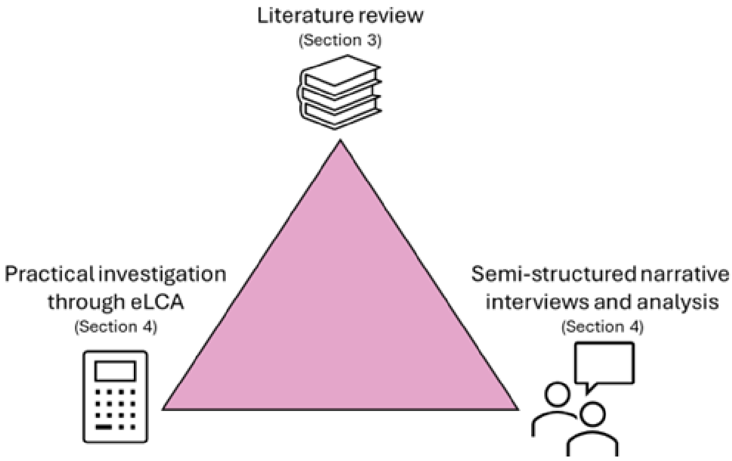


Figure 2. Illustration of the applied methodological triangulation approach

2.1 Semi-structured narrative interviews and analysis

During the application of the semi-structured narrative interviews and analysis, the approach passes through four stages: data collection, transcription, narrative analysis, and deconstruction. The four stages build upon each other, as illustrated in Figure 3.

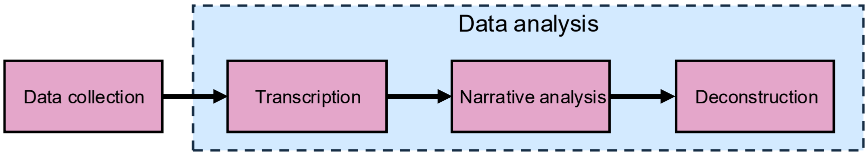


Figure 3. Illustration of the approach in the semi-structured narrative interviews and analysis.

The interviews are performed following the approach outlined by Robson et al. (2016), in five stages: introduction, warm-up, main body of the interview, cool-off, and closure.

The content of each stage of the interview follows the interview guide presented by Zayed et al. (2025). The main body of the interview is conducted following a semi-structured narrative approach, following the elicitation stage presented by Zayed et al. (2024), where the interviewer has prepared a list of main and elaborative questions to guide the interview towards the desired subjects. Generic examples of these questions are presented in Table 1.

Table I. Generic excerpt from the main body of the interview from the interview guide utilised in the interview. Table adapted from Zayed et al. (2024)

Question type	Generic example question
Main questions	Which projects have you been involved in recently? Can you tell a bit about the project?
Elaborating questions	How was the intention you are mentioning integrated into the building/design? Who are the building users? How will the building be used?

The data analysis is performed based on the interview recording, and passes through the three stages: Transcription, Narrative analysis, and Destruction, described in the following subsections. The identified narratives are deconstructed into social intent, which describes how the building users should feel or behave, and the design choice, which describes the object or change to the building design that is intended to provoke, give or result in the social intent being realised for the building users (Zayed et al., 2024; Zayed et al., 2025).

2.2 Practical investigation

The practical investigation assesses/investigates/explores how and which scope can be applied in an eLCA for assessing the environmental impact of social intents. Through the case studies, the practical investigation will explore the potential to perform an eLCA while aligning with both existing eLCA methodologies as well as the perspectives and practices present in the work of architects.

The applied eLCA approach follows the method outline in the ISO 14000 series (International Standards Organization, 2008a, 2008b), and the European standards EN15804 and EN 15978 (European Committee for Standardization, 2011, 2019). The process includes four phases: goal and scope definition, inventory analysis, impact assessment, and interpretation.

Goal and scope: The goal of the study is to assess the GWP of social intents, based on the design choices associated with them and the collected interview data. The functional unit applied in the study is based on the social intent and encompasses the material quantities associated with the design choice associated with the individual social intents. In this regard the applied functional unit aligned with the definition of the functional unit given in ISO 14075 (International Standards Organization, 2024). Further limitations to the scope of the study are applied by only basing the study on the stages A1-A3, B4, C3 and C4 and applying a reference study period of 50 years, aligning with the eLCA methodology applied in the Danish Building Regulations (Danish Authority of Social Services and Housing, 2023). The applied method differs from the Danish Building Regulations by not including module B6 (operational energy), as the inclusion of the social intents into a building project is not expected to impact the B6 module, as the Danish approach to B6 includes the assessment of energy use, not reflecting the building's actual energy use. The applied eLCA methodology differs further from the methodology in the Danish building regulations, as the cut-off rules and guidelines from the regulations are not applied in this study. The identified design choices concern building and design elements that are not included in the eLCA following the Danish regulations.

Inventory analysis: The inventory analysis is performed by identifying material flows associated with the design choices. The flows are identified based on available project material and photographs provided by the interviewed architects during the interview. When the exact material flow could not be identified based on the provided material, estimations have been made based on the available information and prevailing practices.

The material flows are used to calculate the GWP of the individual design intentions based on data from the database ÖKOBAUDAT (The German Federal Ministry for Housing, 2024). The datasets are selected to best represent the materials in the design choice, with regard to manufacturing process, material composition and manufacturing place.

Impact assessment and interpretation: The impact assessment is performed by summarising the impacts from the identified material quantities, resulting in the impact being expressed in terms of kg CO2-eq for the design choice associated with the identified social intents.

3 Literature review

The global emissions of greenhouse gases, typically presented as CO_2-equivalent emissions, are exceeding the planetary boundaries and are therefore at risk of permanently disrupting the Earth's climate by pushing it out of the Holocene (Richardson et al., 2023). In response to this responsibility, the building and construction industry has turned to performing eLCAs as a tool to assess environmental impacts across the entire life cycle of materials and buildings.

The application of eLCA in connection to the built environment started in the late 1990s and has increased rapidly in the 21st century (Buyle et al., 2013). This rapid increase in the application of eLCA in the building and construction industry is further supported by the inclusion of eLCA into prevailing building certification systems (e.g., BREEAM, LEED, and DGNB). Later inclusion of eLCA into legislation and regulation in countries including Denmark, the Netherlands and Sweden (Barjot & Malmqvist, 2024) and most recently in directives from the European Parliament (European Parliament, 2024).

These different applications of eLCA have all tried to make eLCA accessible and applicable, not only in a vacuum, but also in terms of making the results comparable and relevant in the context of the built environment. In doing this, the approaches have defined varying goals and scopes, which are seen both in the certification systems, regulations and in existing research, as studies or eLCAs with the same goal and scope allow for direct comparison. Previous studies have shown that goal and scope in eLCA in the context of housing are primarily focused on emissions of greenhouse gases (GHG), expressed in kg CO2-equivalents. The applied functional units are most commonly applied based on gross floor area and to a lesser extent per capita, and with building life spans ranging between 50 and 120 years, with 50 years being the most widely applied (Ruiz-Valero et al., 2025). These perspectives are further echoed in the Danish building regulations (Danish Authority of Social Services and Housing, 2023), where the functional unit is per square meter per year, with an assessment period of 50 years.

The modules defined in the goal and scope vary between individual studies (Ruiz-Valero et al., 2025), as well as different countries' regulations and legislations (Frischknecht et al., 2019). The most commonly included modules include A1-A3, A4, A5, B4, B6, C3 and C4 (Frischknecht et al., 2019; Ruiz-Valero et al., 2025). The Danish building regulations adhere to common practice by including modules A1-A3, A4, B4, B6, C3, and C4, with A4 reported independently of the other included modules (Danish Authority of Social Services and Housing, 2023).

4 Practical investigation

The following two case studies have been selected to investigate the proposed method and definition of the functional unit. All the cases have been collected following the data collection methodology in section 3.1 and following the methodology for analysis and deconstruction of social intents in section 3.2.2. The identified social intents, design choices and their environmental impacts are presented in the following subsections.

4.1 Case 1

The building has previously been a part of an industrial site constructed in the late 19th century, in a multicultural metropolis. The building was transformed to have facilities that could be used as both an event space and office spaces, with the transformation being concluded in 2010. The building, during the period between its active use as part of the industrial site and the time of transformation, was used as both a shelter for squatters and a venue for hosting raves and parties, resulting in a building that was significantly marked by its previous use before its transformation. Further adding to the challenges related to the building, the building is located in wetlands, which poses a risk of severe flooding.

When talking about the building, the interviewee brought up the choice to keep existing graffiti visible in the building despite the building developer questioning this choice: "*The graffiti is staying there, and I said: Well, there are many eras of this building. It had 100 years as a manufacturing plant, but it had 20 years of being a destination for people from all over the world, as a rave, as a palace for raves. And during this time all of this graffiti was put in place. So, there is a palimpsest of history here […]. If you have your event here, all the events will have and enjoy and in fact feature the graffiti, not just hide from it.*"

One of the social intents associated with the building was to keep it connected to its history, both as an industrial building and as a venue that had hosted parties and raves. In the interview, this was highlighted by the interviewee when talking about how the building developers were questioning keeping graffiti visible in the building. This quote, in connection with the context of the interview, leads to the identification of a socially oriented design intent and its deconstruction into a social intent and a corresponding design choice.

Social intent: Keep the history of the building visible by not only showing that the building has previously been an industrial building but also illuminating its history as a place for graffiti and raves.

Design choice: Keep the existing graffiti visible by not cleaning it off the walls or hiding it behind new wall cladding or paint.

The functional unit, based on the social intent, is therefore to give visitors to the building a sense of the building's history through the visibility of the original graffiti artwork during the building's new lifetime.

Based on the design choice, no additional material has been added to the building project to facilitate the social intent. Instead, it has been decided not to add painting or wall cladding to cover up or remove the graffiti. This results in no added material flow to the building project, but rather a reduction of material compared to the developer's original idea. As there are no increases to, or substitutions in, the materials or material flows, the environmental impact of the social intent and corresponding design choice is 0 kg CO2-equivalents.

4.2 Case 2

The building was previously used as an office building and was renovated in 2022 to accommodate a new group of users, while maintaining its office function. Following the move to this building, the department organisation of the building users also changes from having four departments, each in a different location, to being one department with all employees having their workspace in the same building.

During the interview about the building, the interviewee highlighted the canteen area's role as a natural meeting point, designed to encourage building users to interact with each other while enjoying the space. An example of this is seen in the quote below, where the architect talks about the addition of a glass wall dividing the canteen area from the hallway and the choices associated with the glass wall. The architect is providing multiple statements about the design of the canteen area and the reasoning behind individual design choices. One example is seen in the following quote, focusing on the glass wall: "[...] *this is also an addition* [Interviewee referring to the glass wall] *and it's actually 42 decibel glass. So, it's a high-performance acoustic glass, it's not that expensive, but the effect is very nice. And then they know that. They stay and have a good time. They are also more happy. They probably wouldn't notice the difference, they knew that there has been taken extra care.*"

Through this quote and the wider context of the interview, the architect highlights both the design choice and the social intent behind the design choice.

Design choice: adding and keeping the building users informed about the 42 dB glass wall between the canteen area and the hallway.

Social intent: making a space where the building users want to spend their time, enjoy being there together with their coworkers, while simultaneously knowing that their comfort and enjoyment have been considered by the project designers.

Based on this, the functional unit which is applied in the study is to contribute to realising the social intent through the installation of the 42 dB glass wall, which will be maintained throughout the entire lifetime of the building (50 years).

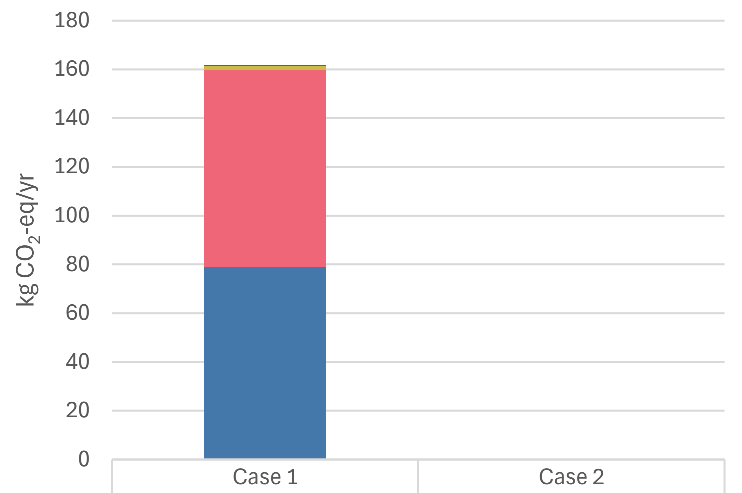
Table 2. Data used in the assessment of the environmental impact of Case 2. The material quantity of the walls is based on drawings provided by the architect. The materials' lifespan is based on the Danish lifespan table (Levetidstable) (Haugbølle et al., 2021). The dataset of the GWP originates from the Ökobaudat (The German Federal Ministry for Housing, 2024)

Material	Quantity	Material life span [yr]	GWP [kg CO2-eq/m2]	GWP [kg CO2-eq/yr]	Dataset name
Glass wall	16,71 m^2	25 years	241.86	161.66	Curtain walling - VFF - Curtain walling in aluminium profiles

The material flow associated with this functional unit is presented in Table 2. The quantities are based on project material provided by the interviewed architect.

4.3 Sum up

The emission of CO_2 equivalents from the two assessed cases is presented in Figure 5, where the emissions are expressed as kg CO_2-equivalents per social intent per year, with an expected lifetime of the building of 50 years. The expected lifetime of the building affects the environmental impact, as it is presumed that the social intent should be present in the building's entire lifetime, and that the design choice, therefore, must be maintained for 50 years.



	Case 1	Case 2
Total	161.66	0
C4	0.25	0
C3	1.74	0
B4	80.83	0
A1-A3	78.84	0

Figure 5. Stages in the eLCA. Figure adapted from ISO 14040 (International Standards Organization, 2008a).

The results of the practical investigation further show that the environmental impact of social intents can be neutral if the intent is associated with the design choice of not adding anything to a building project.

5 Conclusion

The results presented in this paper explored how a scope for assessing the environmental impact of the inclusion of socially oriented design intents can be set to align with both existing eLCA methodologies in the building and construction industry, while simultaneously aligning with the practical approach in the argumentation, reasoning and articulation of social intents and their corresponding design choices. Through a triangulation approach, different perspectives and existing practices were introduced. The literature review showed that the commonly used approach to eLCA within the building and construction industry is to perform the eLCA with a scope that limits which modules are included and with a functional unit based on either building size (per m^2) or based on the number of users (per capita). The interviews with practising architects revealed that the way they reiterate social intents and their corresponding design choices are not aligning with this functional unit, as the architects primarily talk about the social intents and design choices as individual instances, independent of the building size or the number of building users.

Based on the presented practical investigation, it is concluded that the functional unit for assessing the environmental impacts of social intents can be effectively aligned with architects' perspectives in their work. The results thereby support the proposal of using a functional unit based on a per social intent approach when assessing the environmental impact of social intents. Even though the functional unit does not align with the functional unit commonly applied in building eLCA studies, the conversion between the proposed unit and commonly used units are feasible, as it would only require the environmental impact of the social intent to be divided with either the number of building users (per capita approach) or by the gross floor area (per square meter approached). The practical investigation further supports the possibility of aligning the included modules with those in the Danish Building regulations. However, the investigation in this study does not include the B6 module, as social intents do not have a significant impact in that regard.

The results from the presented practical investigations demonstrate the early steps towards developing and adapting the eLCA methodology to be used for assessing the environmental impact of social intents present in the building design. The application of the proposed methodology, which bases the functional unit in the eLCA on the social intent, enables the comparison of environmental impacts across different social intents relevant to building design. The use of the proposed goal and scope aligns with commonly included eLCA modules and bases the functional unit on a per social intent approach in assessing the environmental impact of social intents. Therefore, this is a viable option for early design stakeholders to support informed decision-making regarding both social and environmentally focused parameters simultaneously, thereby bringing them closer to having a positive impact on the overarching sustainability of a building, in contrast to today's more narrow and one-dimensional assessments.

5.1 Future works

This study allows for multiple directions of future development, as it only encompasses the early steps towards developing the methodology. This includes further exploration into the selection and potential alignment of the functional unit with existing life cycle assessment methodologies, including eLCA, sLCA and LCC. The methodology will further benefit from being tested on and applied to more case studies, through which the robustness of the methodology can be strengthened to 1) ensure its applicability to large variations in design choices (e.g., adding, removing, or substituting materials in the design), 2) address the zero impact scenarios similar to Case 1. Further work should explore the relationship between complexity and the magnitude of social intent, the realised social values, and the size of the corresponding environmental impact. Finally, future work can focus on making the methodology accessible and applicable for early design stakeholders by integrating it into a decision support tool for practical use.

Acknowledgements
We would like to formally express our sincere gratitude to all the participants who graciously contributed their time and insights during the interviews. Furthermore, thank you to Martha og Paul Kerrn-Jespersens Fond for providing the required funding for participating in the conference.

Funding
This work was supported by the European Union Horizon 2020 research project PROBONO under grant agreement no. 101037075.

Data Availability Statement
The original contributions presented in the study are included in the article's material, further inquiries can be directed to the corresponding author.

Conflicts of Interest
The authors declare no conflict of interest.

References

Barjot, Z., & Malmqvist, T. (2024). Limit values in LCA-based regulations for buildings – System boundaries and implications on practice. *Building and Environment*, *259*, 111658. https://doi.org/https://doi.org/10.1016/j.buildenv.2024.111658

Biskjaer, M. M., Kamari, A., Jensen, S. R., & Kirkegaard, P. H. (2019). Exploring blind spots in collaborative value creation in building design: a creativity perspective. *CoDesign*, *17*(4), 374-391. https://doi.org/10.1080/15710882.2019.1654521

Buyle, M., Braet, J., & Audenaert, A. (2013). Life cycle assessment in the construction sector: A review. *Renewable & Sustainable Energy Reviews*, *26*, 379-388. https://doi.org/https://doi.org/10.1016/j.rser.2013.05.001

Danish Authority of Social Services and Housing, Bygningsreglementet (BR18), (2023).

Entwistle, J. M. K., & Rasmussen, M. K. (2022). Fra indsigt til forandring: Et indblik i en arkitekturantropologisk praksis. *Jordens Folk*, *56*(2), 131-141. https://tidsskrift.dk/jf/article/view/132630

European Committee for Standardization. (2011). EN 15978:2011.

European Committee for Standardization. (2019). EN 15804:2012+A2:2019.

Directive (EU) 2024/1275 of the European Parliament and of the Council of 24 April 2024 on the energy performance of buildings (recast), (2024). http://data.europa.eu/eli/dir/2024/1275/oj

Frischknecht, R., Birgisdottir, H., Chae, C. U., Lützkendorf, T., Passer, A., Alsema, E., Balouktsi, M., Berg, B., Dowdell, D., Martínez, A. G., Habert, G., Hollberg, A., König, H., Lasvaux, S., Llatas, C., Rasmussen, F. N., Peuportier, B., Ramseier, L., Röck, M., . . . Yang, W. (2019). Comparison of the environmental assessment of an identical office building with national methods. *Sustainable Built Environment D-a-Ch Conference 2019 (Sbe19 Graz)*, *323*(1), 012037. https://doi.org/10.1088/1755-1315/323/1/012037

Haugbølle, K., Mahdi, V., Morelli, M., & Wahedi, H. (2021). *BUILD levetidstabel* [Rapport](Version 2021)

International Standards Organization. (2008a). ISO 14040.

International Standards Organization. (2008b). ISO 14044.

International Standards Organization. (2024). ISO 14075.

Kristoffersen, A. E., Kamari, A., & Petersen, S. (2023). *Comparison of social quality criteria in building sustainability certification systems* the 11th International Conference on Life Cycle Management, Lille, France.

Kristoffersen, A. E., Schultz, C. P. L., & Kamari, A. (2024). A critical comparison of concepts and approaches to social sustainability in the construction industry. *Journal of Building Engineering*, *91*, 109530. https://doi.org/10.1016/j.jobe.2024.109530

Love, P. E. D., Holt, G. D., & Li, H. (2002). Triangulation in construction management research. *Engineering, Construction and Architectural Management*, *9*(4), 294-303. https://doi.org/10.1108/eb021224

Richardson, K., Steffen, W., Lucht, W., Bendtsen, J., Cornell, S. E., Donges, J. F., Druke, M., Fetzer, I., Bala, G., von Bloh, W., Feulner, G., Fiedler, S., Gerten, D., Gleeson, T., Hofmann, M., Huiskamp, W., Kummu, M., Mohan, C., Nogues-Bravo, D., . . . Rockstrom, J. (2023). Earth beyond six of nine planetary boundaries. *Sci Adv*, *9*(37). https://doi.org/10.1126/sciadv.adh2458

Robson, C., Robson, C., & McCartan, K. (2016). *Real world research* (Fourth Edition. ed.). Wiley.

Ruiz-Valero, L., Arceo, A., Kesik, T., Touchie, M., & O'Brien, W. (2025). Life cycle assessment of housing and neighbourhoods: A systematic review. *Renewable and Sustainable Energy Reviews*, *210*, 115249. https://doi.org/10.1016/j.rser.2024.115249

The German Federal Ministry for Housing, U. D. a. B. (2024). *ÖKOBAUDAT* Version 2024-I). https://www.oekobaudat.de/no_cache/en/database/search.html

Vallance, S., Perkins, H. C., & Dixon, J. E. (2011). What is social sustainability? A clarification of concepts. *Geoforum*, *42*(3), 342-348. https://doi.org/10.1016/j.geoforum.2011.01.002

Zayed, Y. N. H., Kristoffersen, A. E., Lohm, G., Kamari, A., & Schultz, C. (2024). The Anatomy of an Architect's Argument: Formally Capturing Socially-Oriented Design Intentions in the Built Environment. Proceedings of the 2024 European Conference on Computing in Construction,

Zayed, Y. N. H., Kristoffersen, A. E., Lohm, G., Kamari, A., & Schultz, C. (2025). A Formalization Framework for Integrating Social Design Intentions into Digital Building Models. *Sustainability*, *17*(17). https://doi.org/10.3390/su17177739

Zimmermann, R. K., Skjelmose, O., Jensen, K. G., Jensen, K. K., & Birgisdottir, H. (2019). Categorizing Building Certification Systems According to the Definition of Sustainable Building. *3rd World Multidisciplinary Civil Engineering, Architecture, Urban Planning Symposium (Wmcaus 2018)*, *471*(9), 092060. https://doi.org/10.1088/1757-899x/471/9/092060