

Filling the gaps - Circular transition of affordable housing in Denmark

Larsen, V. G.; Tollin, N.; Antonucci, V.; Birkved, M.; Sattrup, P. A.; Holmboe, T.; Marella, G.

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Filling the gaps

Circular transition of affordable housing in Denmark

V G Larsen¹, N Tollin¹, V Antonucci², M Birkved¹, P A Sattrup³, T Holmboe⁴
and G Marella²

¹University of Southern Denmark, Odense, DK

²DICEA, University of Padua, IT

³Danish Association of Architectural Firms, Copenhagen, DK

⁴Dissing + Weitling A/S, Copenhagen, DK

E-mail: vgl@iti.sdu.dk

Abstract. The building industry accounts for about 40% of all climate impacts, stemming from construction and renovation processes, use of buildings and demolition, disposal and recycling of buildings and building materials. The Danish Parliament passed a Danish Climate Act in 2020 to reduce greenhouse gas emissions by 70% by 2030, and an action plan in 2021 to create a Circular Economy (CE) in DK that can support the achievement of climate neutrality by 2050. About 20% of the Danish housing stock is affordable housing with approx. 560.000 affordable housing homes, inhabited by nearly 1 million out of 5.8 million people. In 2020 the Danish Government decided on the most significant overall housing agreement to set aside EUR 5,5 billion for ‘Green renovations’ and the building of new affordable housing. Building and renovating affordable housing in Denmark can thus become significant drivers for the Danish building industry's transition to CE. Therefore, developing integrated tools and methodologies for life cycle thinking and CE assessment for the built environment is necessary. We have identified four significant gaps in this endeavour in a previously released literature review: For CE to succeed, it is necessary to take a circular view of the life cycle of buildings, which includes the service life phase, the reuse phase and the recycle phase; To achieve CE, it is necessary to continue research regarding the possibilities of integrating Life Cycle Assessment (LCA), Life Cycle Cost (LCC) and Social Life Cycle Assessment (S-LCA) into Life Cycle Sustainability Assessment (LCSA); S-LCA needs further maturation and development; It is imperative to focus upon operationalising LCSA for practitioners in all phases of a building's life cycle. This paper aims to outline a strategy for analysing and discussing these four gaps and their interrelation in-depth and suggest an action research proposal to understand better how to bridge the gaps from a research perspective.

Keywords: Social housing, affordable housing; LCA; LCC; S-LCA; LCSA, circular economy

1. Introduction

The Danish Parliament passed the Danish Climate Act [1] in 2020 to reduce Denmark's greenhouse gas emissions by 70% by 2030. Additionally, in 2021, the Danish Government released an action plan to create a Circular Economy (CE) [2] in Denmark to support the achievement of climate neutrality by 2050 and the decoupling between economic growth and consumption of natural resources.



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The building industry accounts for about 40% of the climate impact in Denmark, stemming from construction and renovation processes, use of buildings and demolition, disposal and recycling of buildings, and building materials [3]. The affordable housing sector is the largest single sector in the Danish building industry. 20% of the Danish housing stock is affordable housing, with approximately five hundred sixty thousand affordable housing units inhabited by almost 1 million people out of a Danish population of 5,8 million people [4].

Throughout the years, increasing funds for construction and renovation of affordable housing has been used as a lever to increase growth during periods of recession to create more jobs in the construction and service sector. Thus, a parliamentary agreement was reached in 2020, allocating 4 billion. EUR from the National Building Fund (LBF) for renovating the existing housing stock of affordable housing in 2020-2026 to support a social and green transformation. Renovation of 72,000 units was initiated in 2021 for EUR 2.4 billion, and EUR 1.5 billion will be set aside for future renovations until 2026. The renovation scheme intends to increase employment in the construction industry and address an economic downturn created by the COVID19 pandemic. In addition, renovations mean up to a 40 per cent reduction in energy consumption and improved indoor climate for tenants in their homes [5, 6].

The renovation scheme is expected to increase employment due to the economic downturn created by the COVID19 pandemic. In addition, renovations mean 30-40 pct less energy consumption and the tenants' indoor health care benefits.

Building and renovating affordable housing in Denmark can thus become significant drivers for the Danish building industry's transition to CE. CE in construction is about saving and reusing building materials and keeping materials and construction products in cities and buildings' economic circuits with the highest possible value for the longest time. In addition, CE is a way to ensure sustainable management of the earth's resources and develop new economic opportunities for companies through new business models [7-9]. Therefore, it is necessary for the Danish authorities and stakeholders in the construction value chain to assess the efficiency and effectiveness of CE and how the best possible value for the invested funds is achieved through CE.

2. Research background

The paper at hand is a part of an overall research project called "Circular transition of affordable housing: Generating environmental, economic and social co-benefits by design"[10]. This research project aims to promote the transition of Danish affordable housing to a CE by developing a framework for assessment, evaluation, and cost-benefit analysis of the efficiency and effectiveness of CE while integrating environmental, economic and social co-benefits [10, 11]. Furthermore, the research project concerned hypothesises that architectural companies play a central role in the CE transition of the affordable housing sector through re-thinking systems by design.

Table 1. Research questions in the research project concerned

<i>Research questions</i>	<i>Status</i>
1. What are the challenges in assessing circular economy for the built environment? [12]	Literature review
2. How can these challenges be analysed and understood in depth so that the research can support the affordable housing sector's transition to CE through <u>changing building practices from linear to circular phase models?</u>	The paper at hand
3. How can architectural design processes foster a transition to circular economy for the affordable housing sector?	Paper in progress
4. How can the social co-benefits of a transition to circular economy for affordable housing be measured and assessed, and how can end-users and stakeholders' participation through co-design and informed decision-making foster a transition to circular economy for the affordable housing sector?	Consecutive paper

The research project [10] aims to combine life cycle thinking methodologies with supporting the evidence-based decision-making and the design process of architectural firms and social housing organisations through value chain innovation. The research project runs through four phases, as shown in Table 1. Each phase responds to research questions, exploring the organisational, sectoral, and political premises to establish recommendations for evaluating CE transition for the affordable housing sector.

The purpose of the research project is to support The Danish Association of Architectural Firms (DA)[13] and The National Building Fund in Denmark (LBF)[14] in creating markets for new CE services and solutions for affordable housing, scalable to other housing types in Denmark as well as internationally impacting policy-making. DA is a trade association with approx. seven hundred twenty member firms (by June 2022), and LBF is an independent institution developed by the Danish affordable housing organisations (i.e. associations of end-users/renters) and regulated by the state through legislation. LBF aims to support and develop the social housing sector, which is self-financing through various subsidy and loan schemes.

3. The research question for this paper.

We conducted a literature review, "What are the challenges in assessing Circular Economy for the built environment?"[12] (Table 1, no. 1) to understand the complexity of life cycle assessment as a tool for evaluation and cost-benefit analysis of the efficiency and effectiveness of CE.

It was an objective of the literature review (LR) to map the status of integration of Life Cycle Assessment (LCA), Life Cycle Costing (LCC), and Social Life Cycle Assessment (S-LCA) into Life Cycle Sustainability Assessment (LCSA) to understand current limitations and knowledge gaps related to existing life cycle tools [12]. Another objective was to discuss how and to what extent life cycle thinking can be integrated into the built environment to support the transformation of the construction sector from linear to circular economy, with the potential to support sustainable development on a large scale.

We appointed four knowledge gaps by recording trends in the scientific literature assessed in the LR, which are lined up in Table 2:

Table 2. Knowledge gaps in "What are the challenges in assessing Circular Economy for the built environment?"[12]:

Circularity	It is necessary to support a systemic shift by developing a comprehensive, genuinely circular view of life cycle phases. A circular argument should include the usage (of buildings) phase, the reuse/recycle (of structures and materials) phase, and the other life cycle phases within the construction and real estate sector.
Integration	Further research in the integration of LCA, LCC and S-LCA is necessary to develop LCSA for building processes and proper assessment tools for the built environment. Furthermore, efforts should be made to harmonise the three methods and develop coherent data and KPIs, quantitative and qualitative.
S-LCA	S-LCA is still not very well defined and described in the scientific literature. Therefore, S-LCA needs even further maturation and development.
Usability	Throughout the reviewed articles, it is stressed that life cycle methodologies are not adequately operational and usable yet, for the actors in the design and building processes in the built environment.

The article at hand describes how we examine and understand whether the four knowledge gaps ascertained in the scientific literature also occur when clients / end-users and architectural offices plan and execute affordable housing renovations in concrete planning, design, execution, and usage phases. For this purpose, the following research question (RQ) is raised to guide the research;

How can the knowledge gaps be analysed and understood in depth so that the research can support the affordable housing sector's transition to circular economy through circular phase models?

Why and how we aim to handle the knowledge gaps through quantitative and qualitative stakeholder surveys, interviews, observations and workshops is described in parts 3.1.-3.4. of the paper at hand. Transition theory will form the research appropriate for understanding change processes in systems and their application within CE. Significant national policies for sustainability, climate, building and renovation of affordable housing and the existing linear construction and renovation processes guide the direction.

These studies form the basis for an overlay of policies, specifications and activities in a circular process model for masterplan processes to renovate affordable housing in Denmark. Findings are summarised in section 4 to direct the continuous research hereafter to answer the overall project hypothesis about "Circular transition of affordable housing: Generating environmental, economic and social co-benefits by design," [10] elaborated upon in part 5.

3.1. Circularity

The forty-two scientific articles of the LR [12] show an overall tendency to see building processes as linear rather than circular. Most (3/4) articles demonstrate Cradle-to-Gate (C2G) and/or ISO 14044 (an international standard for environmental management and life cycle assessment) approaches. Some articles point out that the general phase understanding in the construction industry is not yet circular, as the LCA's standards (which are also the standards that many want to use for S-LCA) are linear (C2G). Very few articles (three) relate to Cradle-to-Cradle (C2C).

A linear process understanding with a massive focus solely on LCA creates a risk of neglecting the importance of aspects of social and economic sustainability. It is, therefore, necessary to address social and economic sustainability to develop a comprehensive, genuinely circular view of life cycle phases in construction processes - because everything is connected in circularity.

Most articles stressed that it is essential to focus on policy-making and decision-making in the early stages of a building or renovation process, regardless of scope. However, this approach is not demonstrated in the reviewed articles, as two-thirds deal with the design and construction phases, less than 1/2 deal with the usage phase, and less than 1/4 deal with demolition and the recycling phase [15, 16]. The usage phase is defined in some articles as significant but is generally not addressed, although it is essential for S-LCA.

Today, the usage and recycling phases are undervalued in the renovation industry's construction practice (e.g. by clients/end-users and architects). Daily work focuses on immediate design and execution costs [17] and not on the long-term economic co-benefits to gain in the usage and recycling phases. Unfortunately, that neglect may prevent us from achieving the goals of the Paris Agreement and gaining benefits for society, clients, end-users, consultants and contractors. Therefore, there is a need to look at costs and value creation in building processes in an integrated way. It is necessary also to highlight the early phases and include the usage (of buildings) phase and the recycling (of structures and building materials) phase beyond the design and execution phases to support the systemic shift from linearity to circularity.

Several climate and sustainability policies have been developed to ensure Denmark's ability to deliver on the Paris Agreement. As a foundation for understanding the Danish governing within the field, we look into relevant policy frameworks for sustainability, climate and CE as guides to action; e.g. The Danish National Strategy for Sustainable development [18], The Danish Climate Act [1], The Danish Circular Economy action plan [19], and The Waste Order [20].

We assume that the knowledge gap about circularity we identified in the scientific context also occurs when politics shall become operational in the construction industry through the planning, design, execution and usage phases of affordable housing renovation projects. However, because the construction sector is reluctant to develop integrated methods, it tends to stick to business as usual to

avoid further increasing complexity to the already high complexity of the construction processes [21]. Therefore, in a consecutive paper (Table 1, no 4), we explore the readiness for change and the pros and cons of the value chain's existing linear phase models versus the circular phase models through 10-15 structured dialogues with housing companies and architects in the affordable housing sector.

3.2. *Integration*

Until 2011, most life-cycle tools were used independently from each other and mainly about "simple" stand-alone products.

After 2015, we see an increasing focus on integrating two or three assessment methods, still, however, predominantly on "stand-alone" products.

Most of the articles reviewed are solely about the LCA. LCA is a quantitative and reasonably mature methodology with international standards for definitions and processes (ISO 14040). However, some scientific articles discuss the shortcomings of LCA and criticise LCA for being too static because the results of the LCA are snapshots rather than trends. In addition, standardised evaluation systems for the LCA as they are today are most often still product-oriented and based on a linear understanding that does not include the reusing/recycling phases in the construction process [16, 22].

2/3 of the forty-two articles reviewed describe the integration of the LCA and the LCC [23-25]. LCC is considered relatively mature, albeit more temporal and diverse than LCA, and is based on the life cycle perspective, still however missing the reuse/recycle aspect [26]. Temporality in LCC is an issue that distinguishes it from LCA. In addition, standardised LCC is based on a linear economic understanding of costs that is not unfolded in a perspective that demonstrates the socio-economic value creation through a circular economy.

Thirteen out of forty-two articles describe the integration of LCA, LCC and S-LCA in the LCSA and point out that S-LCA is a necessary, albeit immature and complex area considered essential for a systemic and integrated life cycle approach. There is a discussion about different data and quality in the methods mentioned in important articles [27, 28]. 3/4 of the forty-two articles address these differences in LCA, LCC, and S-LCA and other life-cycle tools at a more general level

Several articles see integrating the three methods, LCA, LCC and S-LCA, into a holistic framework, LCSA, as fitting. They claim that documentation of the absolute sustainability of urban development and buildings [29, 30] can be supported in a circular phase model. The purpose of integration is to avoid a burden shift from the environmental dimension to the social and economic dimension of sustainability and to promote the ability to evaluate both costs and value creation. In that perspective, it is not enough to assess environmental performance. It is necessary to develop further the ability to evaluate life cycle costs, the total cost of ownership and socio-economic gains and pains and social aspects such as will, effort, consumer patterns and behaviour for CE to succeed.

We assume that the knowledge gaps concerning the integration of LCA, LCC and S-LCA arise when politics must become operational in the construction industry through planning, design, execution and usage phases in affordable housing renovation projects. Therefore, we explore the building value chain through 10-15 qualitative interviews and structured dialogues with decision-makers among housing organisations and architects about current planning processes in the affordable housing sector concerning the use of LCA, LCC and S-LCA in a consecutive paper (Table 1, no 4). In addition, we run 1-2 workshops with architectural firms and housing associations to evaluate social value creation in practice (e.g. architects' practice) to analyse the architectural design and participatory design (of housing organisations) processes for social housing.

We include relevant policy frameworks for the construction sector as guides for action, National Strategy for Sustainable Construction [31] and The Danish voluntary building class [32] to understand the political setup for construction industry regulation.

3.3. *S-LCA*

Social sustainability and value creation are about how the built environment creates value for the developer, the users and the society regarding inclusion, consumption, advantages, disadvantages, benefits and costs associated with the built environment. Social sustainability and value creation are also about the qualities that construction projects have regarding, for example, cultural heritage, cohesion, productivity, learning, health, urban life, and job creation. The impact categories can be as diverse as behaviour, safety, number of deaths, human rights, architectural quality, diversity, historical continuity, governance, socio-economic impacts and labour market policies [33, 34].

Social sustainability and value creation, being this diverse, are challenging to measure and describe unequivocally. In addition, the different construction and renovation industry players view social value creation differently. Nevertheless, social issues can be linked to the economy and end-users sustainable will, effort, and behaviour. Thus, social value creation is assumed to significantly impact the circular economy's success.

S-LCA may be a way of documenting and evaluating social sustainability and value creation. However, there are no unambiguous evaluation systems for S-LCA or evaluation of social issues. Furthermore, the LR shows that the S-LCA generally suffers from a lack of attention and difficulties laying out criteria and indicators of social sustainability. Besides, S-LCA indicators have different perspectives from LCA indicators. This aspect generally means uncertainty in claims for the impact categories addressed in the S-LCA.

Several reviewed articles identify the evaluation of social sustainability and value creation as necessary for absolute sustainable development. It is, therefore, essential to become more evident in categorisation, definitions and characteristics of social sustainability and value creation so that the development of the field can take place on an informed basis.

We assume that architects have a unique role in ensuring social value creation in the built environment through their effect on creating the results hereof [35]. Therefore, we focus specifically on the architects' role and the expectations from the housing associations to evaluate social sustainability and value creation in the renovation of affordable housing.

The topic of capacity building to evaluate social sustainability and value creation in the renovation of affordable housing is explored through qualitative methods, such as 2-4 questionnaire surveys and 8-10 qualitative interviews and structured dialogues with architects and housing associations in currently ongoing research (Table 1. No.3) on planning and design processes, with a focus on identifying criteria and indicators of social sustainability, value creation and the willingness to pay for this.

As a foundation for understanding and analysing the setup regarding the affordable housing sector, we include relevant policy frameworks for the affordable housing sector as guides for action: The Social Housing act [6], Action plan – “Denmark without a parallel society – No ghettos in 2030” [36], and we analyse the affordable housing sector framework: the Federation of Non-profit Housing providers (BL), the National Building Fund (LBF), the affordable housing associations, tenants and the municipalities.

3.4. *Usability*

Despite the relative maturity of the LCA method, there are still many understandings of what an LCA is. Moreover, a shared understanding of what needs to be measured is not yet. However, national LCA and LCC tools (LCAByg and LCCByg) are being developed in Denmark [37-40].

The scientific literature points out that life cycle assessment methods are different and challenging to apply to actors in the construction value chain, which is linked to issues addressed in the description of the three previously mentioned knowledge gaps: *Circularity* (current practice is linear and not circular and there is no look at value creation); *Integration* (complex due to the different nature of the three evaluation forms, indicators, time and data) and *S-LCA* (as an evaluation method S-LCA is immature in comparison with LCA and LCC, and exact definitions of social value creation have not yet matured to an operational level). Furthermore, quantitative and qualitative indicators are essential to assess life cycle methods, which are treated differently in all three assessment methods.

This diversity makes it difficult for actors in the construction value chain to use life cycle methods comparably and consistently. In addition, construction projects consist of many sub-elements that must be assembled into structures and become part of society at micro, meso and macro levels. Therefore, the complexity of evaluating to a comparable, truthful, appropriate and sober level is high due to the many chains and levels of building components.

At the same time, innovation in building materials and components is taking place at a high pace, and new knowledge from last year may be old news for next year. Therefore, LCA methods, generally considered technically common property today, may become obsolete when something other than what the methods evaluate becomes essential tomorrow.

Moreover, it makes it challenging to manage life-cycle methods that sustainability assumptions change very quickly as new knowledge influences and challenges the beliefs for life cycle assessments [21]. Therefore, we assume that it is necessary to develop building processes to become more agile and to include uncertainties associated with life cycle methods. Furthermore, we assume that the knowledge gaps concerning the usability of life cycle assessment methods identified in the scientific context also emerge in the housing organisations and architects' practice through the planning, design, execution and usage phases in affordable housing renovation projects.

Therefore, we examine the level of competencies, needs and expectations concerning the usability and quality of existing assessment tools through 10-15 surveys, interviews and structured dialogues with decision-makers in affordable housing organisations and architects in the building value chain on planning processes in the affordable housing sector in a currently ongoing investigation (Table 1. No.3).

Several policies guide the planning of construction and renovation processes in Denmark. Therefore, we include the relevant knowledge of the building sector framework as action instructions: The Danish Building Act [41], Danish Building regulations [42], and Building sector framework and value chain as references in our analysis.

4. Discussion: Filling the gaps

We expect to understand the four knowledge gaps through the activities mentioned in sections 3.1-3.4. We, therefore, summarise an overall assumption that more phases are to be assessed in circular phase models than standardised linear phase models regarding renovation processes in the affordable housing sector construction projects.

At the same time, all three dimensions of sustainability should be assessed, preferably as integrated, in circular phase models to comprehend circular building processes and achieve absolute circularity in the renovation processes.

We suggest the following vital actions per phase to achieve circularity:

- *Screening*: Assessment of recyclable resources and the environment for an upcoming renovation project should be defined and identified in the initial stages of a renovation process, as this is important for as well considerations of the environment, as upon the economy and the (social) willingness of the end-users to reuse and recycle buildings and building materials;
- *Building brief*: The intention and requirement specification, the level of ambition for circularity, as well as the economy should be assessed during the programming phase;
- *Design / Innovation*: During the design phase, design strategies for user behaviour, circularity and execution, including demolition, should be defined and assessed;
- *Execution*: During the construction phase, coordinated efforts for demolition should be defined and assessed, as well as prepared for delivery and operation;
- *Usage phase*: During the usage phase, assessment and evaluation should be carried out in collaboration with end-users regarding optimal operation and maintenance;
- *EOL / Disposal*: What is considered end-of-life in common considerations and typically related to the demolition and disposal of building materials should instead be seen and assessed as potential

resources for future construction and renovation projects, thereby looping to the initial phases in the circular phase model

It is worth paying particular attention to defining the *screening/building brief*, the *design/innovation* and the *usage* phases appropriately because of the possible value creation in more areas than solely environmental sustainability. Therefore, we focus on how and when integrated life cycle assessment can support the circular economy in these phases, as shown in Figure 1.

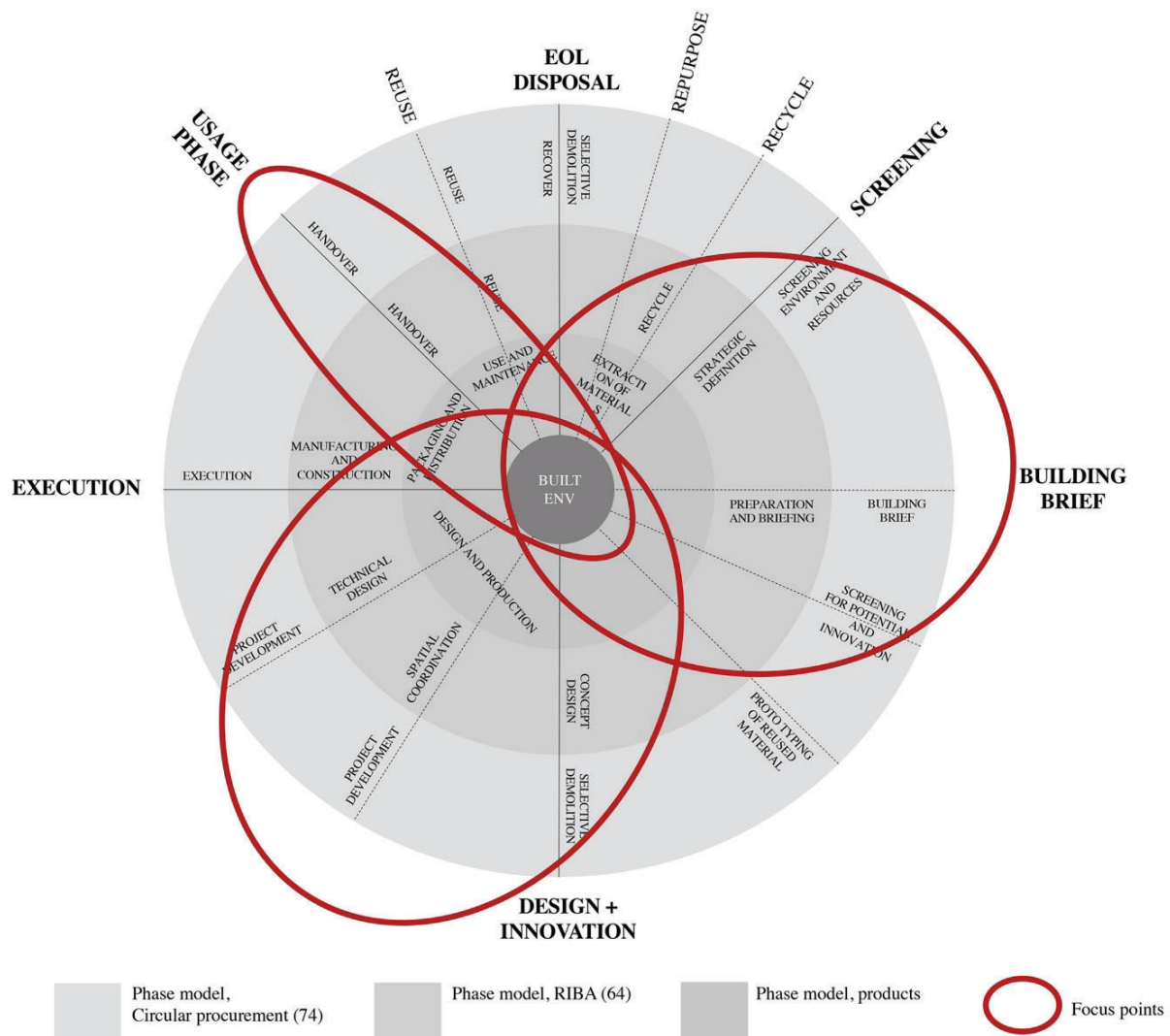


Figure 1. Focus points for potential value creation through a circular economy. Adapted and modified from “What are the challenges in assessing Circular Economy for the built environment?”[12].

5. Perspective – a proposal for a circular life cycle model for the renovation of affordable housing.

The circular phase model, to be generated through the research described in sections 3 and 4, will guide the development of a framework for decision support for affordable housing associations and architects as an answer to the aim of the overall research project, to support the "Circular transition of affordable housing: Generating environmental, economic and social co-benefits by design".

The described methodology will lay the ground for exploring our hypothesis that architectural companies play a crucial role in the CE transformation of the affordable housing sector by designing socially sustainable housing and implicitly documenting the achieved social value creation.

Such a phase model will impact existing decision models for affordable housing renovation. Therefore, the assumption on the importance of the *screening/building brief*, *design/innovation* and *usage* phases is to be confirmed in a case study about planning processes, looking into the current planning practice (by housing associations and architectural offices) of preparing the processes for the renovation of affordable housing, going beyond the scope of the article at hand.

Today, financial and technical support for the renovation of affordable housing in Denmark requires a process where an applicant answers to three schemes, Scheme A (Masterplan), Scheme B (Design) and Scheme C (Construction), in three applications.

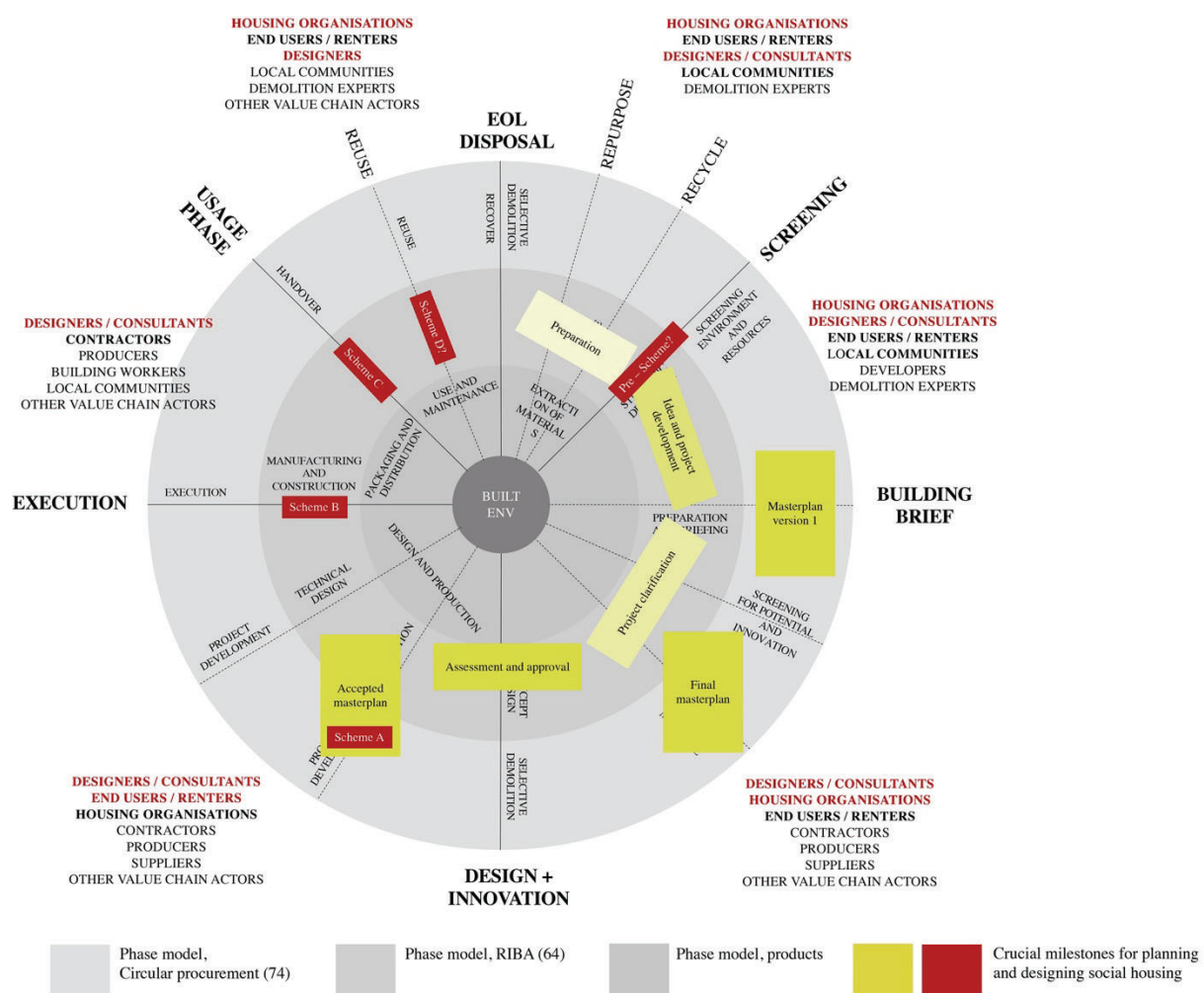


Figure 2. A circular phase model, including Schemes A, B and C and possible additional schemes. Adapted and modified from “What are the challenges in assessing Circular Economy for the built environment?”[12].

The concrete renovation of affordable housing is organised around this approval process, resting upon the idea of optimising construction costs. The applicant is the builder, i.e. a housing association, who prepares the applications [43] for LBF [5]. LBF provides the housing sector with financial support,

expert knowledge and various statistics and IT tools based on a defined and commonly known procedure consisting of:

- *Scheme A (Masterplan)* is the framework for the housing association's renewal and future-proof of a housing department. It forms the basis for the housing association's collaboration with the architect, the consultant, the municipality and LBF. From the need for a renovation being considered until Scheme A is approved, the overall planning typically goes through four phases; (i) Preparation; (ii) Idea and project development; (iii) Project clarification; (iv) Assessment and approval. Scheme A application is sent when the residents and the association board approve the final master plan (containing the project, preliminary budget for the master plan, financing and rent consequences) at a ward meeting.
- *Scheme B (Design)* application is sent when an explicit project material has been prepared and a price has been obtained for the contractor's work. The Scheme B application must always be approved by the association board (the client), the municipality and LBF. Once all parties have approved scheme B, the construction work can begin.
- *Scheme C (Construction)* application is sent when the construction work has been completed and the terminated construction accounts for the overall plan have been prepared. Scheme C must be approved by the association board (the client), the municipality and LBF.

We look into this decision process and explore how the Schemes A, B and C can be inscribed into the circular phase model, as we suggest in Figure 2. As a result, we define how and where to assess CE and whether more or less assessment is necessary (tentatively proposed as Pre-scheme and Scheme D in Figure 2) in a consecutive paper (Table 1, no. 4).

Finally, we test the circular phase model in a concrete renovation project. The aims are to identify the drivers and barriers to overcome the four knowledge gaps and assess value creation on all parameters, not solely on environment and economy, but also on social co-benefits through architectural design.

With this, we critically discuss the concept of CE and aim to understand how and when integrated life cycle assessment could occur in a circular construction process to support evidence-based decision-making and contribute to the transition to a circular economy for the affordable housing sector. Below this aim is another aim to identify the type, time and format of information that can support housing associations' and architects' decision-making at the various design stages in a social cost-benefit analysis regarding efficiency and effectiveness [44, 45] of CE.

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