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The housing construction chain in motion:

A systems approach to accelerate the transition to a circular housing construction system based on circular and conceptual building

GRADUATION THESIS

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Preface

Dear reader,

I am happy to present my graduation thesis as the final product of the master Metropolitan Analysis, Design and Engineering. The thesis is a result of five months of research and writing, starting from february 2022 and lasting until july 12, the day that I will present and defend this thesis. With this thesis two memorable years at the AMS Institute in Amsterdam are coming to an end.

The built environment and specifically housing have interested me since the start of my MSc MADE. Therefore, I decided to focus my thesis on opportunities for sustainable housing construction. I am also interested in affordable housing, since I believe that housing is a basic need; everyone should be able to live in a comfortable house within their budget. Therefore, I started with the idea to combine circularity in housing construction with affordable housing. Nonetheless, eventually there was not a full overlap between the two topics and I had my hands full with all the data and ideas on circularity in housing construction. Thus, in the end I decided to focus solely on circular and conceptual building and leave affordable housing out of the scope.

I did not want my research to end up covered in dust in an academic drawer, as I believe that the gap between academic research and society/practice should be closed. Therefore, I am very grateful that I got the opportunity to combine my research with an internship at AM, one of the largest area developers in the Netherlands. Because of this, I have been able to get in contact with a large variety of actors in housing construction in and outside the company. The goal of this internship was to translate the academic research into a white paper with a call-to-action for practitioners in housing construction, and that is what we did! The white paper has been presented on the Provada, a three-day real estate event in the RAI, Amsterdam, where many practitioners and other enthusiasts took a copy home. The white paper is available online here. The white paper has been positively received, which is a nice validation of the impact I hoped to make with my research.

I want to thank Maarten Markus, my supervisor at AM for his enthusiasm, passion and support. The internship has given me a lot of unique opportunities and I think we are both proud of the result of the research. Furthermore, I want to thank Angel Lázaro and Marietta Haffner, my academic supervisors from WUR and TUD for challenging me academically to make the most out of my thesis. Lastly, I want to thank all the participants and interviewees of my research. I really enjoyed the discussions, interviews and the inspiring insights you gave me. On a personal note, I would like to give a word to all my fellow MADE students, who are not only fellow students, but dear friends that have supported me throughout the process. Besides, I want to thank my family and friends for their love and infinite support.

I look forward to the opportunities that will come after this thesis and I hope that you will enjoy reading this work,

Malika van de Weerd
July, 2022

Executive summary

Problem statement

One of the sectors that has a large share in reaching the climate targets is the built environment. The Climate Agreement that is presented in 2019 shows that they are one of the sectors that should urgently reduce their emissions. Nonetheless, there is a blind spot in tackling the CO2 emissions in the built environment: more than one third of all CO2 is emitted during construction and maintenance of buildings. These are material-related emissions: 'embodied carbon.' This is problematic, since the Netherlands has a large national task to accelerate housing construction to around 100,000 homes per year. In order to take these aspects of sustainable and affordable development into account, it is essential to reconcile the climate goals and the housing task.

Circularity is a major area of interest within the field of sustainable development. The principles of the circular economy allow us to move towards a more sustainable development, by maintaining added value in products for as long as possible and minimizing waste. These principles make the concept a relevant means to the goal of housing construction in line with the climate targets. The transition to a circular construction system has started, with an increasing number of housing construction projects that include principles of circular and conceptual building (CCB). Even though the first steps in CCB have been taken, the current Dutch housing construction system is still largely embedded in its traditional, linear system. Large-scale CCB not only requires an innovative construction perspective, but entails a transition in the entire housing construction system. All actors in housing construction are part of this transition, each having their own role and interests. All together, accelerating the transition to a circular housing construction system to make CCB the new standard is a major challenge.

Research questions

This thesis attempts to understand the barriers and enablers that the actors in housing construction experience in the transition to a circular housing construction system, in order to find out what they need to make CCB the standard in new-build. Accordingly, the aim is to understand what support actors in the housing construction system require to accelerate the transition to a circular system based on CCB. The focus of this thesis is limited to CCB in housing construction in the Netherlands. It includes all phases of housing construction, from land to planning, to design, construction, use and maintenance, since circularity requires an integral view encompassing all these phases. The final objective is to deliver a practical tool that present-day actors in housing construction could use if they engage in CCB and wish to accelerate the transition to a circular system.

The following main research question is posed:

What do actors in the internal socio-technical system require to accelerate the transition to a circular system based on circular and conceptual building, and how could these requirements be implemented?

In order to answer the main research question, this thesis answers five subquestions:

Sub RQ1: *Which actors, values and processes are present in the internal system of present-day housing construction, and what are the opportunities for CCB in this system?*

Sub RQ2: *Which barriers and enablers are identified in the literature for transitioning to a circular system based on CCB in the built environment?*

Sub RQ3: *How are barriers and enablers to accelerate the transition to a circular system currently experienced by project developers?*

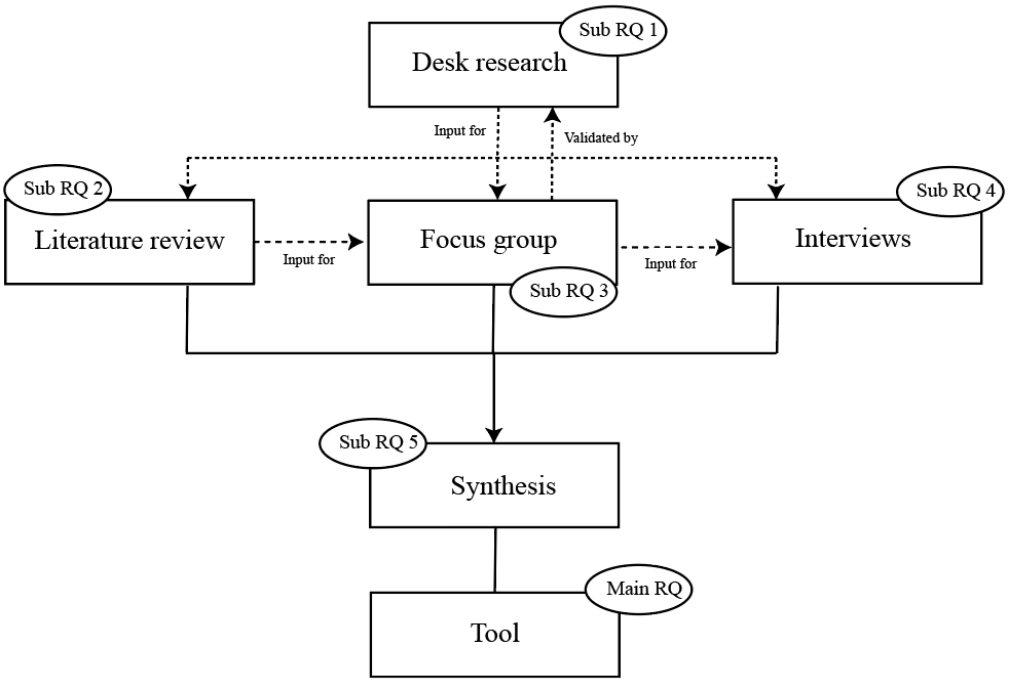
Sub RQ4: *How are barriers and enablers to accelerate the transition to a circular system currently experienced by actors in the internal socio-technical system and stakeholders in the external landscape?*

Sub RQ5: *Based on the synthesis outcomes, which interventions support actors in the socio-technical system, and where in the system could these be implemented?*

Research methodology

The study has adopted a systems approach that understands housing construction as a socio-technical system. A 'system of systems approach' serves as a conceptual framework for this study. Transition theory is used as a research frame for analyzing the process from one socio-technical system to another. Transition theory allows for determining the stage of the transitions, so that interventions could be tailored to facilitating the desired change in that stage.

In order to answer the sub-research questions, five phases are developed for this research project with each a respective research method. The flowchart of the research activities is presented below.



Findings

The literature review results in more enablers than barriers. The majority of the barriers are identified in the internal system, whereas the majority of the enablers are identified in one of the external subsystems. The results from the focus group mainly concern barriers and enablers in the internal system. The results from the focus group and the interviews show a predominant focus on barriers and enablers related to the actors in the internal system and the importance of collaboration in the housing construction chain and financial viability. It emerges that in this phase of the transition, actors would mainly benefit from interventions in the *system actors* subsystem. Specific focus is on collaboration between actors in the housing construction chain. All actors must make the transition from a linear to a circular system their common goal, and each actor should fulfill a role with corresponding tasks and responsibilities in the collaboration for the transition to a circular system.

Tool: collaboration for a circular system based on CCB

All actors must make the transition from a linear to a circular system their common goal, and each actor should fulfill a role with corresponding tasks and responsibilities in the collaboration for the transition to a circular system. That is the basis for the tool: collaboration for a circular system based on CCB, that is presented in this thesis (p.83). The tool is developed for municipalities, project developers, architects, contractors, housing corporations and (institutional) investors as actors in present-day housing construction. The tool elaborates on the role that each of these actors could fulfill in a circular system, including their responsibilities and practical suggestions.

Conclusion

The key findings of this study show that the transition to a circular system based on CCB is not particularly a technical challenge, as little barriers were identified on the technical capacity for this transition. Rather, it is a social challenge that requires cultural change in the housing construction sector. The success of the transition to a circular system based on CCB lies in the collaboration between actors in the housing construction chain. There are too many dependencies in the housing construction chain to unilaterally place the responsibility for circularity on one actor. Therefore, transactions and negotiations between the actors should make place for collaboration. More collaboration leads to an integral approach and ultimately to achieving the climate targets.

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1. Introduction

1.1 Problem statement

According to the most recent publication of the IPCC climate report, the effects of climate change are becoming increasingly apparent. The temperature has risen worldwide and the risks and magnitude of the consequences differ per region and ecosystem (IPCC, 2022). The main Dutch climate risks are rising sea levels, prolonged drought or heat, and more extreme precipitation in summer (KNMI, 2021). The goal is to protect the Netherlands against these consequences of climate change, but also to limit further global warming. In order to minimize the consequences of climate change, there are various national and international climate targets. Currently, the targets for the Netherlands are a reduction in greenhouse gas emissions of 49% in 2030, and 95% in 2050 (Rijksoverheid, 2022a). The Dutch national government has made agreements with a variety of sectors about how the Netherlands will achieve these targets.

The Climate Agreement presented in 2019 shows how the construction sector is one of the sectors that should urgently reduce their emissions. Hence, the built environment has a considerable role in reaching the climate targets. This thesis will focus specifically on the housing construction sector. De Circulaire Bouweconomie (2021) explains how the main focus in this sector has been on energy saving as well as eliminating the use of fossil fuels. However, they show that if all future houses are built in line with the current agreements of NZEB (Nearly Energy Neutral Building) and a four percent reduction on energy use in the industry, the CO2 budget for construction will still be exhausted in 2026. They stress that there is a blind spot in tackling the emissions in the built environment: more than one third of all CO2 is emitted during construction and maintenance of buildings. These are material-related emissions, ‘embodied carbon’. Only by tackling the challenge of embodied carbon, the construction sector could largely reduce their emissions and build in line with the climate targets.

This is challenging, since the pressure on the Dutch housing market is currently high. Many people struggle to find a suitable house within their budget and demand exceeds supply. A national task to accelerate housing construction follows to around 100,000 homes per year (Rijksoverheid, 2022b). Hence, in this large housing task it is essential to reconcile the climate targets and construction. Housing construction could then contribute to solutions for the enormous climate challenge, rather than being the problem. It is therefore crucial to investigate opportunities for a way of building in line with the climate targets.

A certain opportunity is circularity; currently a major area of interest within the field of sustainable development. The principles of the circular economy allow us to move towards a more sustainable development by minimizing waste and maintaining added value in products for as long as possible. There are various definitions of ‘a circular economy’, including a growing body of concepts related to the model. The most widely adopted definition of a circular economy is that of the Ellen MacArthur Foundation. They explain the circular economy as ‘an industrial economy that is restorative or regenerative by intention and design’ (MacArthur, 2013:14). These principles make the concept a relevant means to the goal of housing construction in line with the climate targets. Circularity has the potential to positively contribute to major challenges related to the embodied carbon of construction materials and is therefore chosen as the central concept of this study.

Circularity in housing construction has started with an increasing number of projects that include principles of circular and conceptual building (CCB). In this study, working definitions for CCB in line with the City Deal ‘Circulair en Conceptueel Bouwen’ are adopted. This City Deal is set up by AgendaStad as a cooperation between the national government and a large variety of market parties. These parties wish to engage in CCB (AgendaStad, 2022). Circular building is captured by this City Deal as construction with a low environmental footprint and for future reuse. Conceptual building is explained as building from a predesigned, well-thought-out concept. In this context, a concept is seen as a reproducible, yet flexible solution (Huijbrechts et al., 2017). Such a concept has a modular structure with a fixed script, but with flexible rules. A modular concept has a high potential to be a starting point for the transition to a circular system in the built environment due to the predestined characteristics in design for disassembly and reuse (Mackenbach et al., 2021). Besides, the term ‘conceptual building’ is often used in a similar context to industrial building. This relates to the production of prefabricated elements in a factory. This industrialized construction goes increasingly hand in hand with conceptual building, although concepts are not always factory built. Hence, there is not (yet) a complete overlap (DuurzaamGebouwd, n.d.).

Even though the first steps in CCB have been taken, the current Dutch housing construction system is still largely embedded in its traditional, linear system. Large-scale CCB not only requires an innovative construction perspective, but entails a transition in the entire housing construction system in terms of e.g. regulations, valuation, taxation and understanding of the circularity principles. Implementing these principles comes with the use of new technologies, business models and partnerships (Acharya et al., 2018). All actors in housing construction are part of this transition to a

circular system, each having their own role and interests. All together, accelerating the transition to a circular housing construction system to make CCB the new standard is a large and complex challenge. This is confirmed by the actors involved in the City Deal CCB. This thesis attempts to explore the barriers and enablers that the actors in housing construction experience in this transition. This is done to understand what these actors need to make CCB the standard in housing construction.

1.2 Scientific relevance

In the literature on circularity in the built environment much attention has been paid to new biobased solutions (Churkina et al., 2020; De Klijn-Chevalerias & Javed, 2017; Herzog et al., 2021; Jędrzejczak et al., 2021; Van Dam et al., 2018), opportunities for industrial and modular construction (Bertram et al., 2019; Halman et al., 2008; Kyrö et al., 2019; Silva, 2020; Mackenbach et al., 2020), regulation and legislation for a circular built environment (Aertsen et al., 2022; Giorgi et al., 2022; Bilal et al., 2020), circular business models and financial instruments (Lewandowski, 2016; Nußholz, 2017; Guldmann & Huulgaard, 2020) and methods to measure circularity (Heisel & Rau-Oberhuber, 2020; Rahla et al., 2019). These are all factors that contribute to the conditions for accelerating the transition to a circular system in housing construction. Yet, little attention has been paid to what the key actors in the housing construction system need to accelerate this transition. On that account, this research is scientifically relevant because it focuses on the key actors in present-day housing construction, aiming to close the gap of knowledge between the academic literature and practice.

1.3 Societal relevance

The large demand for housing is a nation-wide issue. Nonetheless, the pressure on the housing market is highest in metropolitan areas. The Dutch population has grown explosively in the last century: from 5 million in 1900 to more than 17 million in 2020. As a result, existing cities expanded strongly and rural areas urbanized. This increase is not only caused by the natural growth of the population, but mainly because more migrants, both Dutch and foreign, are settling in the cities (CBS, 2021). Due to the increasing urbanization there is a growing pressure on the housing market of metropolitan areas. The majority of the new-build houses are demanded to be developed in metropolitan areas or as an extension of metropolitan areas (De Nationale Omgevingsvisie, 2022).

Housing is a basic need and The Ministry of Housing and Spatial Planning strives for all Dutch citizens to live in a ‘good, sustainable and affordable house in a liveable neighborhood’ (Rijksoverheid, 2022b). In line with that, the metropolitan society and its planners are confronted with another spatial challenge: climate-proof design of cities. KNMI (2021) emphasizes that cities are vulnerable as they are usually warmer

than rural areas and the extreme precipitation and drought are an increasing challenge for metropolitan areas. Hence, this stresses the need for thinking about the role of housing construction in the development of safe and sustainable metropolitan areas that are 1) resilient to the consequences of climate change and 2) are built in line with the climate targets. CCB allows for integrating these aspects of complexity and climate-proof design, for instance with biobased materials, flexible design and opportunities for disassembly. Thus, a circular housing construction system based on CCB benefits society as it contributes to providing safe, climate-proof and non-transient housing.

1.4 Research scope and objective

This study does not primarily focus on the construction perspective in the upscaling of CCB. The study is rather set out with the aim to understand what support actors in the housing construction system require to accelerate the transition to a circular system based on CCB. The focus of this thesis is limited to CCB in housing construction in the Netherlands. It includes all phases of housing construction, from land to planning, to design, construction, use and maintenance, since circularity requires an integral view encompassing all these phases. Accordingly, the study focuses on the key actors who have an active role in housing development throughout these phases. These actors will be identified further in this thesis. The final objective is to deliver a practical tool. Present-day actors in housing construction could use this tool if they engage in CCB and wish to accelerate the transition to a circular system.

The thesis is organized in the following way. Chapter 2 provides the conceptual framework based on a systems approach. Subsequently, the research questions are provided in chapter 3 in line with the research objective as presented in paragraph 1.2. Accordingly, the research methodology and methods are explained in chapter 4. The remaining part of the thesis proceeds as follows: in chapter 5 and 6 the results from desk research and a literature review are presented and analyzed. Chapter 7 and 8 show the results of empirical research. In these chapters the results of a focus group and interviews undertaken during this research are presented and analyzed. Chapter 9 synthesizes the results from the literature and empirical research, and proposes a practical tool to support the actors in housing construction. Finally, this thesis closes with a conclusion and discussion, respectively chapter 10 and 11, aiming to answer the main research question and to discuss the relevance as well as the limitations of this study.

2. A systems approach to socio-technical transitions

As explained in the introduction, upscaling CCB in the traditional, linear system is complex. Therefore, a transition to a circular system is fundamental. Circularity requires an integrated approach including all actors and stakeholders in housing construction. Referring to a '**transition** to a circular **system**', this study adopts a systems approach where housing construction is analyzed as a socio-technical system. Accordingly, this chapter elaborates on transition theory and proposes a conceptual framework. This framework serves as a rationale to investigate the transition to a circular system.

The first section (2.1) of this chapter explains housing construction as a socio-technical system. The following section (2.2) theoretically captures transitions, by elaborating on transition theory. The final section of this chapter (2.3) presents the conceptual framework central to this research.

2.1 Housing construction as a socio-technical system

A socio-technical system is explained by Geels (2005: 446) as a 'cluster of elements, including technology, regulation, user practices and markets, cultural meaning, infrastructure, maintenance networks and supply networks'. A socio-technical system could be perceived as a system that is created and (re)produced by a variety of interacting actors. Each actor has their own values and interests, as well as preferences, strategies and resources (Geels, 2005). This research aims attention at the transition from a linear to a circular system in housing construction. Geels (2005) emphasizes housing as an example of a societal function fulfilled by a socio-technical system. This research argues that this transition cannot be achieved by solely focusing on the technical level of working towards circular construction. Technical aspects are directly related to social structures. Hence, this transition requires the integration of the social and technical structures, which is theorized and represented as a socio-technical system (Geels, 2005; Ornetzeder & Rohracher, 2009).

2.2 Transition theory

Transition theory focuses on systemic changes and how these occur within economies, technologies, institutions, cultures and beliefs across scales, sites and temporal manifestation (Campbell-Johntson et al., 2019). They argue that transitions could for instance be driven by 'regulatory measures and normative expectations, infrastructure development, knowledge sharing, suasive measures and financial support' (2019: 1233). This is supported by De Jesus & Mendonça (2018), in their study on transitions

towards the circular economy. In this process, the role of both society and technology in achieving sustainable change should be acknowledged (Rotmans et al., 2001). They provide a theoretical approach that includes technological, institutional and sociocultural transformations in describing socio-technical transitions.

As this study deals with a complex socio-technical system, transition theory is used as a research frame for analyzing the process from one socio-technical system to another. Moving from a linear to a circular system in housing construction occurs as a period of uncertainty. This period is recognized by continuous change, fluctuation and disruption. Transition theory allows for determining the stage of the transitions, so that interventions could be tailored to facilitating the desired change in that stage.

Rotmans et al. (2001: 17) and Geels (2005: 451) similarly conceptualize four different phases of transition: 1) *a pre-development phase* where the status quo does not visibly change, 2) *a take-off phase* where the state of the system begins to shift, opening up for a process of change, 3) *a breakthrough phase* where socio-cultural, economic, ecological and institutional system change react to each other - leading to acceleration and visible structural change and 4) *a stabilization phase* where the new dynamic equilibrium is reached and the speed of the change decreases.

Transitions are complex non-linear, multi-level and multi-stakeholder processes, which makes it hardly possible to control them (Campbell-Johnston et al., 2019; Geels, 2005). However, even though challenging, the direction and trajectory of the system processes can be influenced with ‘actions that are flexible, experimental and guided by the precautionary principle to prevent undesirable lock-in and enable promising innovations.’ (Campbell-Johnston et al., 2019: 1233). Iacovidou et al. (2021) criticize the multi-level perspective by Geels (2005) and the four phases of transition by Rotmans et al. (2001). They argue that their systems thinking approaches are relevant in understanding interventions and how interventions could be made. Yet, the complementing transition theories are relatively weak in pointing out where in the system these interventions are most valuable. As Iacovidou et al. (2021) believe in the importance of this, they propose a different systems-based approach. This approach is called the ‘system of systems approach’. They postulate that there are various interconnected subsystems, and defining these help to understand where in the system interventions could be made. This approach is applied in understanding the complexity of, and transitioning to a circular economy.

2.3 Conceptual framework

This thesis aims to understand what support actors in the housing construction system require to accelerate the transition to a circular system. Therefore, it is relevant to

understand where in the system interventions are valuable in the current stage of the transition. Hence, this thesis follows the system of systems approach by Iacovidou et al. (2021). Their framework is adopted as the conceptual framework for this research. This section presents and explains this framework by introducing the various interconnected subsystems as mentioned in the last section.

Internal system

To start with, they illustrate a system with boundaries that separate the system from its surroundings. Within these system boundaries they argue for three interconnected subsystems. These subsystems are functioning as a whole and form the ***internal*** system. This conceptualisation of a system is visualized in figure 1. Iacovidou et al. (2021) conceptualize three interconnected subsystems in the internal system: actors, values and processes. *Actors* are all individuals, parties or organizations who are involved in the internal system, and directly or indirectly influence the movement and processing of resource flows. Actors are driven by their interests and socio-economic, political and technical processes. Accordingly, they hold a certain power for influencing the processes. *Values* in this study are related to the positive and negative impacts in the environmental, economic, social and technical domains (as the four domains of value) as a result of the processes and actors. These values help evaluate the internal system, providing insight into the cause and effect relationships and reflecting the potential of driving change. This helps to identify points where value is captured or could be created (Iacovidou et al., 2021: 24790). *Processes* are the resource flows from production, to consumption, to end of life management. These subsystems are adopted in this study to conceptually define the internal system.

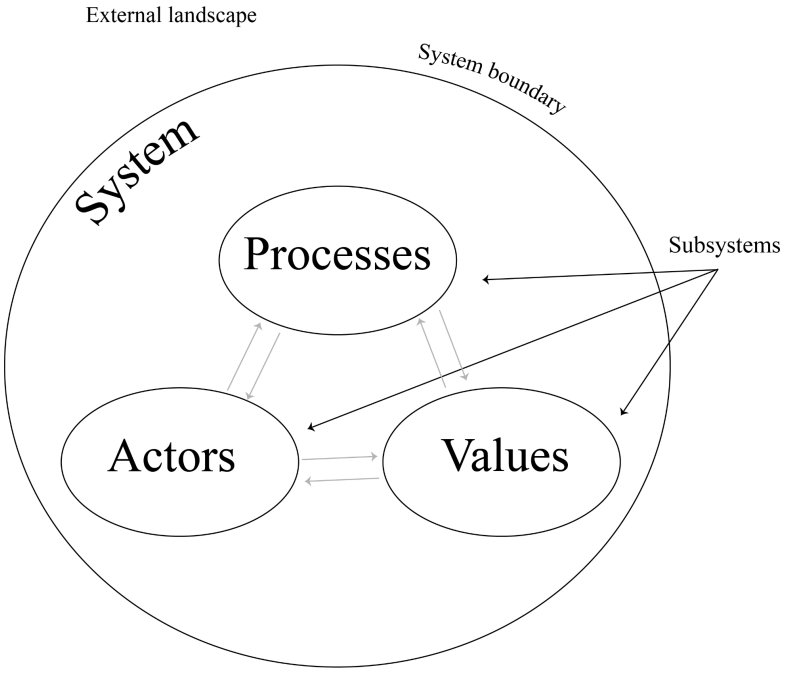


Figure 1 *Representation of the internal system. Adopted from Iacovidou et al. (2021: 24790)*

External landscape

Furthermore, Iacovidou et al. (2021) illustrate an external landscape as a space where the internal system is situated, which affects the dynamics between the internal subsystems (processes, values and actors). They argue that there are various subsystems in this external landscape. These subsystems form the environment of the internal system. These subsystems develop and respond to change interactively, which may impact the success of system interventions (Iacovidou et al., 2021). This approach suggests including five external subsystems. Synergistic relationships between (internal and external) subsystems might bring about a set of interconnected changes. These changes enable desired transition.

These ***external*** subsystems are able to affect the behavior of the system directly and indirectly, as illustrated in figure 2. The first external subsystem, *governance, regulatory framework and political landscape,* concerns the political aspects related to the socio-economic and techno-economic aspects of the housing construction system. The second external subsystem, *activities performed by business and the market,* concerns the organizational relations that cause and drive resource flows through the system, to meet human and societal needs. Third, *technology, infrastructure and innovation level,* concerns the technological and infrastructure elements that are integral part of the housing construction system as well as the innovation with these elements promoting a circular system. Fourthly, *patterns of behavior relating to meeting human and societal needs,* concerns the impact of behavioral patterns that are evolved over time as a result of meeting human needs and the human ability to organize socially to provide these needs. The last external subsystem, *natural resources and provisioning services,* concerns the ecosystems impacted by resource consumption, production and management and the role of provisioning services in supporting circularity.

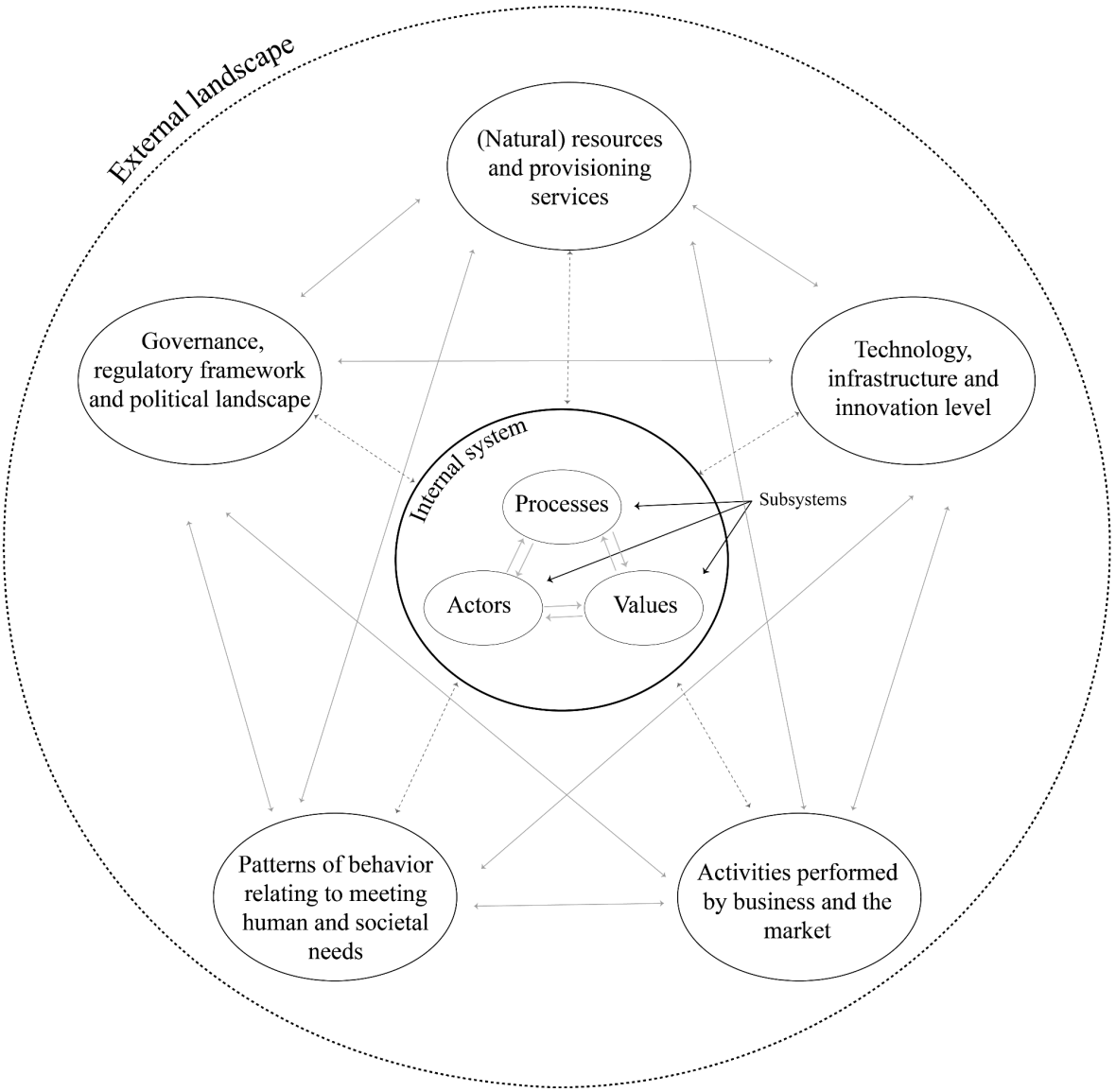


Figure 2 *Representation of the internal system situated in the external landscape. Adopted from Iacovidou et al. (2021: 24792)*

This theoretical representation of **internal** and **external** subsystems allows identifying and understanding required changes towards sustainable transition. Besides, it allows for an approach to decide *where* in the system interventions are relevant to bring about (synergistic) change for transitioning to a new socio-technical system. This helps to align priorities and transform current practices, accelerating the transition towards a circular system. Hence, this conceptualisation by Iacovidou et al. (2021) serves as a fundamental framework in this research in providing guidelines for categorization of barriers, enablers and - eventually - interventions to support the actors in the socio-technical system of housing construction.

3. Research questions

The problem statement in the introduction implies the urgency for a radical change in the housing construction system. Although the first steps in CCB are made by the actors in this socio-technical system, housing construction is still largely embedded in a linear system. A transition to a circular system is required to make CCB the standard in housing construction. Circularity in housing construction has started with an increasing number of projects that include principles of CCB. Hence, following the conceptualization of the phases of transition by Geels (2005) as discussed in chapter 2, the transition is now in the *take-off phase (2)*. In this phase the state of the system begins to shift, opening up for a process of change. This study aims to explore how to accelerate this transition from a linear to a circular system. Hence, move through the second phase to the *breakthrough phase (3)*. In that phase acceleration and visible structural change lead to the final phase, *stabilization (4)*.

As argued by Rotmans et al. (2001) the role of both society and technology should be acknowledged in achieving sustainable change. Section 1.2 of the introduction shows how the majority of the literature currently focuses on the technical aspects of the socio-technical transition. To add new insights to the current body of knowledge, this study focuses rather on the social frame of reference. The actors in the internal system of housing construction are central to this research. The study has the aim to explore what they require to accelerate the transition. Accordingly, interventions to support these actors are presented in a practical tool. However, it is important to mention that the research is not bound to the internal system. It might result that the actors in the internal system mainly require support from one or multiple of the subsystems in the external landscape. Accordingly, the main research question of this study is as follows:

What do actors in the internal socio-technical system require to accelerate the transition to a circular system based on circular and conceptual building, and how could these requirements be implemented?

Several subquestions are developed to guide the research towards answering the main research question. In order to tailor the conceptual framework to this thesis, the first aim is to understand the various actors, values and processes in present-day housing construction and explore opportunities for CCB. The following sub-research question is posed:

1) *Which actors, values and processes are present in the internal system of present-day housing construction, and what are the opportunities for CCB in this system?*

Secondly, this study aims to get familiar with the general barriers and enablers that are identified in a transition to a circular system in the built environment. This research is based on a literature review. The following subquestion is posed:

2) Which barriers and enablers are identified in the literature for transitioning to a circular system based on CCB in the built environment?

The barriers and enablers identified in the literature serve as a basis for an empirical exploration. An aim of this study is to add to the literature on CCB specifically for housing construction with present-day, real-context experiences. The empirical research consists of two parts: a focus group with employees from a project developer and various interviews. The following two sub-questions are posed:

3) *How are barriers and enablers to accelerate the transition to a circular system currently experienced by project developers?*

4) *How are barriers and enablers to accelerate the transition to a circular system currently experienced by actors in the internal socio-technical system and stakeholders in the external landscape?*

Consequently, the results are synthesized. Finally, the goal is to develop a practical tool to support actors in housing construction to accelerate the transition to a circular system based on CCB. Using the system of systems approach, this tool is focused on parts of the external landscape or internal system. The conceptual framework helps to indicate *where* interventions could be implemented. The following sub-question is posed:

5) Based on the synthesis outcomes, which interventions support actors in the socio-technical system, and where in the system could these be implemented?

After this fifth and final subquestion an answer to the main research question is formulated in the conclusion. The answer follows up on the fifth subquestion. The next chapter provides an overview of the research methods before moving on to the chapters that the research questions.

4. Research methodology

Since this research aims to understand what the actors in the housing construction system require to accelerate the transition, this research adopts a qualitative research design. The decision for qualitative research is based on the argument that this usually involves interactive and developmental contact between the researcher and the research participants. This allows for emergent issues to be explored. This results in rich and extensive data based on the experiences and perspectives of actors in the housing construction system, according to the qualitative research guide by Snape & Spencer (2003).

In addition, the study follows the methodological triangulation analysis technique as argued for by Carter et al. (2014). Methodological triangulation concerns the use of multiple methods and data sources in qualitative research in order to gain a comprehensive understanding of phenomena (Patton, 1999). Besides, triangulation is used as a part of a qualitative research strategy to test and promote validity through the merge of information from various data sources (Carter et al., 2014; Johnson, 1997).

This chapter is divided into six parts. First of all, the key concepts are defined (4.1) and the research is operationalized (4.2). Accordingly, the data collection methods are explained (4.3), followed by a section elaborating on the methods for data handling (4.4). The last section of this chapter (4.5) considers appropriate research ethics for this study.

4.1 Definition of key concepts

To start with, the central terms of this research are circular building and conceptual building. The introduction explains these terms. Accordingly, two working definitions are developed for this thesis. Circular building is ‘construction with a low environmental footprint and for future reuse.’ and conceptual building is ‘building from a predesigned, well-thought-out concept where the concept is a reproducible, yet flexible solution’.

The working definitions are developed because the definitions of both concepts could largely differ per context. Yet, this study aims to take on a pragmatic approach during the empirical research. It is important to explore how various actors and stakeholders define and understand these terms, in order to better understand their context of CCB. In the empirical context, the actors are requested to provide their own definition of the

terms from the understanding from their local context. Afterwards, the working definitions are presented so that all participants have the working definitions in mind during the other questions or assignments. This is done to assure similarity, to enable comparison in the data analysis. Eventually, section 8.2.1 is dedicated to how circular building and conceptual building are understood amongst the respondents.

Besides, this study uses the notions of 'barriers' and 'enablers' to indicate certain factors in the internal or external landscape that potentially impede or enhance the transition to CCB. Factors are indicated as 'barriers' if they impede implementation, use or acceleration of CCB. Factors are indicated as 'enablers' if they support or facilitate the implementation, use or acceleration of CCB.

Thirdly, the notion of 'value' is used in various ways in this study. Therefore, it is essential to distinguish the several definitions of value throughout this thesis. Firstly, in section 2.1 the notion of value is used in the explanation of a socio-technical system by Geels (2005), "each actor has their own **values** and interests, as well as preferences, strategies and resources" (p.7). Here, the term 'value' is used to explain underlying reasons for these actors. Moreover, the notion of value is used throughout the thesis in the practical context of a circular system based on CCB. Here the term is used to express the importance or worth of something to someone. An example is found on p.4, "The principles of the circular economy allow us to move towards a more sustainable development by minimizing waste and maintaining added **value** in products for as long as possible." Finally, the notion of value is used in the conceptual framework, as one of the internal subsystems. Here the term value concerns the positive and negative impacts in the four domains as a result of processes and actors. This is explained in section 2.3.

Lastly, this research includes 'actors', 'stakeholders' and 'respondents'. Actors are defined as individuals, parties or organizations in the internal housing construction system. They have an active role in the processes for housing production and they are central in this study. Individuals, parties or organizations outside the internal housing construction system that advise, influence or make policy for the housing construction system are identified as stakeholders. They impact the processes, but do not actively contribute to the production or construction of housing. Respondents are the focus group participants and interviewees. They could be either actors or stakeholders.

4.2 Operationalization

Operationalization allows for systematic data collection and analysis of phenomena that are not directly visible. The conceptual framework adopted from Iacovidou et al. (2021) serves as the foundation of the research. This framework shows the interplay

between actors, values and processes in the internal system, as well as the relationship between the internal and the external subsystems. The purpose of this thesis is to 1) understand *what* support actors require to accelerate the transition and 2) *where* in the system interventions related to this support could be implemented. This is in line with Iacovidou et al. (2021), who argue for the necessity to indicate where in the system the interventions are located in order to align priorities and transform current practices to accelerate the transition to a circular economy.

To come to an answer to this main question, this study is based on various sources of data. These various sources build upon each other following the idea of triangulation. The results from each data collection method are first analyzed apart from each other. Using the subsystems in the conceptual framework helps to understand where in the system barriers and enablers are located. The framework allows for categorization into the internal system or external landscape, and consequently for a categorization into one of the proposed subsystems. The first categorization, internal or external environment, is done by determining whether a theme arises from the housing construction system as the internal system, or from one of the subsystems in the external landscape. In case of an internal theme, further categorization to system actors, values or processes is done - based on the proposed definitions of these concepts (chapter 3.3). In case of an external barrier or enabler, further categorization is done based on the five external subsystems and their definitions. After that, based on the proposed definitions, barriers are distinguished from enablers within the themes.

Each data collection method after the desk research results in a table with an overview of the results per subsystem. This allows for later comparison between the data sources, in order to develop the tool and answer the main research question. The tool is developed to support actors in the internal housing construction system to overcome barriers and use enablers as opportunities to accelerate the transition to a circular system based on CCB.

4.3 Data collection methods

In order to answer the sub-research questions and follow the process as proposed in the operationalisation, five phases are developed for this research project with each a respective data collection method. This thesis aims to build upon literature with qualitative research and empirical data gathering. Nightingale (2009) shows that commonly, triangulation will use a phased methodology where researchers use a certain method for background understanding and follow with another method for data collection. This line of reasoning is followed in this research, as shown in figure 4.

To answer the first sub-research question, desk research is conducted. For the second research question, academic and practitioner literature over the past ten years is analyzed with a literature review technique to identify the general barriers and enablers of transitioning to a circular construction system in the built environment. These insights serve as a basis for the further empirical research. Since the literature review is over the past ten years, the empirical research is done to understand what is currently important with the relevant actors and stakeholders. The empirical research part starts with a focus group with various project developers from the same organization. In the focus group, the insights from the literature review are validated and further explored. Respectively, the insights from the focus group serve as a basis for in-depth interviews with various actors and stakeholders in housing construction. The results from the different data collection processes are synthesized.

Phase 1: desk research on the actors, processes, values and opportunities for CCB

The purpose of the first sub-research question is twofold. First of all, to gain more insight into the various actors, values and processes in the housing construction system. Secondly, to explore opportunities for CCB in this system. The actors and their roles are identified based on desk research with secondary data. Bryman (2016:14) explains desk research as ‘a critical examination of existing research relating to the phenomena of interest and relevant theoretical ideas’. During the desk research, both academic and practitioner literature is explored.

Phase 2: literature review on barriers and enablers for a circular system in the built environment

The second phase continues with a theoretical approach. In phase 2, theoretical literature is reviewed conducting a literature review. There is significant overlap between desk research and a literature review. However, they are distinguished in this thesis as the literature review is a systematic review following a literature review protocol, whereas the desk research takes a rather explorative approach.

The purpose of the second sub-research question is to identify barriers and enablers in the literature for transitioning to a circular construction system in the built environment. Academic and practitioner literature is reviewed following a structured literature review method. Fink (1998:3) defines a literature review as ‘a systematic, explicit and reproducible method for identifying, evaluating and interpreting the existing body of recorded work produced by researchers, scholars and practitioners’.

A literature review protocol is developed, defining the scope of the systemic review based on keywords, sources and year of origin. A literature review is helpful to place

the research in a context of what has already been done on the topic and to gain insights from previous work in a given field. Furthermore, a review of the literature is beneficial for increasing the researchers intellectual capacity and skills as it helps develop a research attitude. Hence, this research conducts a systematic review of both academic and practitioner literature. It believes that effort in this phase helps build a stable fundament for the rest of the research. In the literature review on barriers and enablers, the scope is broadened - taking into account literature on barriers and enablers for circular construction in the built environment in- and outside the Netherlands. This approach is chosen, as the - especially academic - literature on specifically the housing construction subsector in the Netherlands is limited. For the literature review, a keyword search is conducted with a timeframe from 2010-2022. Table 1 presents an overview of the literature review protocol, adapted from the PRISMA checklist by Moher et al. (2009).

Literature review protocol	
Keywords	"circular construction" "circular housing construction" "circular economy" "circular building" "circular built environment" "circular building sector" "building sector" "modular construction" "industrial construction" "barriers" "obstacles" "enablers" "drivers"
Search strategy	title, abstract, year, keywords
Inclusion/exclusion	Included: peer-reviewed academic journal articles, white papers, conference articles, grey literature (all between year 2010-2022) Excluded: full text not available, years outside 2010-2022, non-English/Dutch documents
Databases and sources	Google Scholar (academic literature), consultancy documents, documents from governmental bodies, documents from housing corporations and investors, documents from developers and contractors, documents from consortia

Table 1 *Literature review protocol. Author's own work.*

Phase 3: focus group with employees from a project developer

The first method to acquire empirical data is a focus group, with the purpose to understand the present-day barriers and enablers to accelerate the transition to a circular system based on CCB as experienced by project developers. Petty et al. (2012 : 380) explain this method as a ‘group interview on a particular topic with around 6 - 10 individuals’. This research applies the method of a structured focus group, with multiple structured practices. Petty et al. (2012) argue for a session that lasts between one and two hours, that is audio-taped for transcription. The session consists of an explanation, multiple practices and room for discussion and reflection. A focus group seems a relevant method for this research, as it provides an efficient way to gain rich, empirical data - acquiring a range of views from actors related to the issue. A focus group allows for interaction with the participants and asking follow-up questions to reach an in-depth conversation. Moreover, the researcher could also gain non-verbal information. The focus group protocol is included in appendix B.

This focus group brings together a variety of people with different backgrounds from a project development organization. A project development organization is chosen as they are a spider in the web in the housing construction system. They are in close contact with the municipality, architects, contractors, housing corporations/investors and also with the end user.

Furthermore, the participants have various positions and backgrounds: an area economist who has worked for the municipality, a civil area developer with practical insights from projects, a development manager with a background at a housing corporation, a sustainability manager and a project developer with a background at a contractor. The aim of this focus group is to stimulate participants to have discussion and generate barriers and enablers that are important in present-day processes. They are able to provide valuable insights from various perspectives, based on their role and background. These insights serve as input for the further empirical data generation.

Phase 4: interviews

The fourth research question is set out to understand how these barriers and enablers are currently experienced by actors in the internal socio-technical system and stakeholders in the external landscape. To that end, thirteen interviews are conducted. This allows for capturing individual information from actors in the housing construction system, as well as stakeholders that have a certain view on the housing construction system related to the transition to CCB. The sample of the interviewees in qualitative studies does not need to follow statistical methods. It is rather about finding a balance between the need to obtain a rich experiential description and an equal representation of experiences across the population of possible participants, as argued by Patton (2005). The aim is for the sample to consist of

- actors in the internal socio-technical system and stakeholders in the external landscape that are active in- or have an impact on present-day processes of housing construction
- at least one respondent from each actor group in the internal socio-technical system, as specified and elaborated on in section 5.1
- various stakeholders that have an overarching perspective of the actors, values and processes in the internal socio-technical system.

The overview of respondents is included in appendix C.

The goal of these interviews is to explore in-depth experiences and views of individual actors that each have a different role in the socio-technical system, to validate and further build on the outcomes of the focus group. Hence, it does not aim to reach theoretical saturation. The interview protocol developed covering topics related to the various subsystems of the internal system and external landscape. A variety of questions is predetermined, but there is room for further elaboration per interviewee. Hence, the semi-structured interview approach is chosen, which involves several areas of interests that are pre-determined. These help to guide the conversation (Petty et al., 2012).

Phase 5: synthesis

The results of the theoretical and empirical data collection are synthesized in order to answer the main research question. Furthermore, the outcomes are used to develop the practical tool to support present-day actors in housing construction who wish to accelerate the transition to a circular system. The synthesis requires an exploration of differences and similarities between the theoretical data on circular construction in the built environment, the empirical data from the focus group and the empirical data from the interviews. Figure 3 provides an overview of the various methods. These methods are used to answer each sub-question and eventually, the main research question.

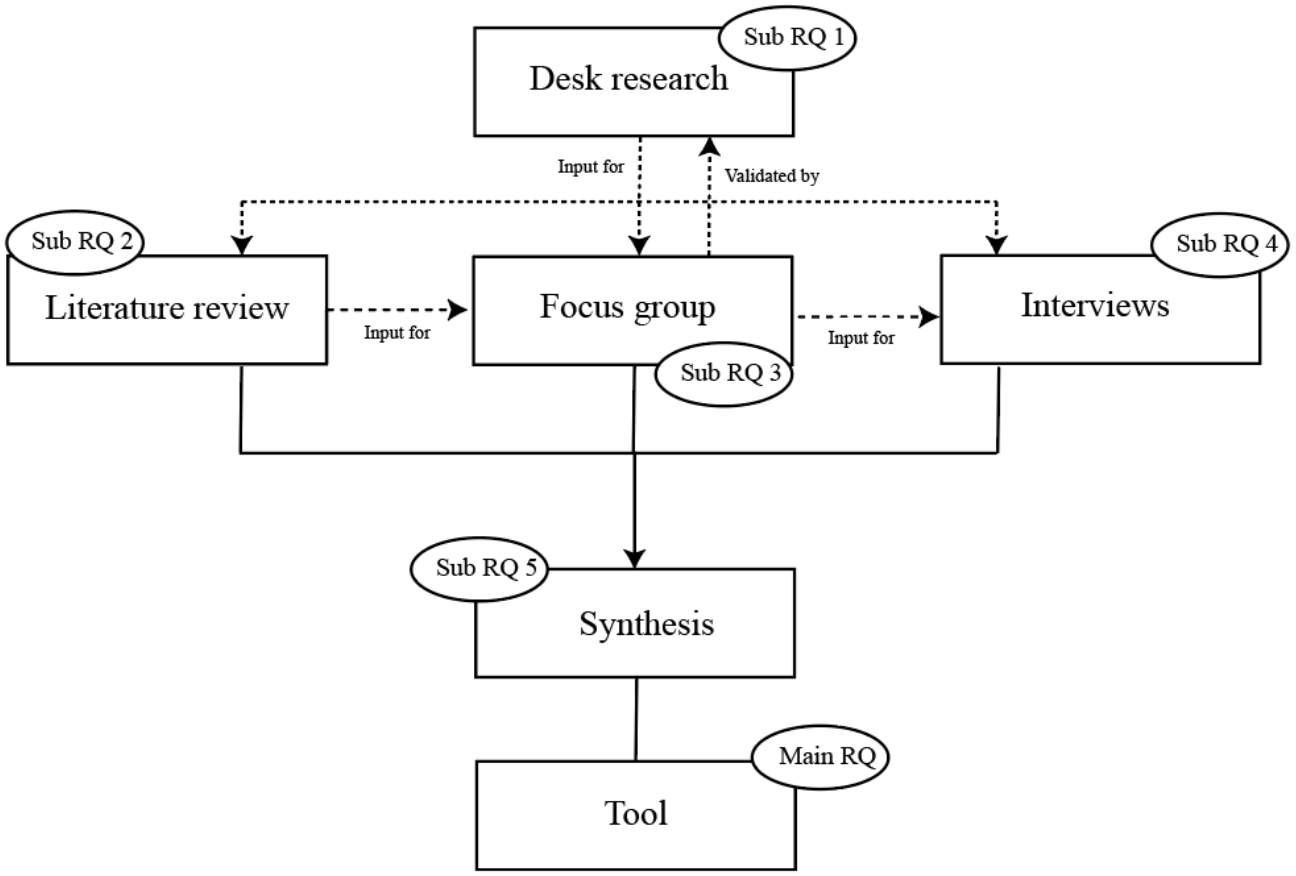


Figure 3 *Flowchart of research questions and research activities. Author's own work.*

4.4 Data handling methods

Phase 1: desk research on the actors, processes, values and opportunities for CCB

This study uses the results of the desk research to develop a context-specific interpretation of the internal system in the conceptual framework. This is the housing construction chain, showing the key actors in the internal socio-technical system and their relations, as well as opportunities for circular processes. This is a simplified interpretation of a complex socio-technical system. The concept version of the housing construction chain is validated by the participants of the focus group. This is done to see if there is a general agreement amongst the participants of the processes and relations between the actors in the internal system.

Phase 2: literature review on barriers and enablers for a circular system based on CCB in the built environment

The literature review follows the protocol as described in figure 3. A table is developed which is filled in with barriers and enablers from the literature. The table is included in appendix A. A barrier or enabler can be mentioned in more than one

source, therefore the table allows to include multiple sources as well as the type of source. Furthermore, the table includes a categorization into the internal or external landscape as well as the various subsystems. From this table, a framework is developed with a clustered summary of the barriers and enablers in different subsystems. This framework is used in the synthesis for comparison with the empirical research.

Phase 3 and 4: focus group with employees from a project developer and interviews

The empirical data from the interviews and the focus group is handled and analyzed in a similar way. Each session is recorded, transcribed and analyzed. The thematic analysis approach by Virginia Braun and Victoria Clarke is used for the data analysis. Thematic analysis is a method for systematically identifying, organizing and offering insight into patterns of meaning (themes) across a data set (Braun & Clarke, 2012: 57). They argue for a six phase approach: familiarization, coding, generating themes, reviewing themes, defining and naming themes and writing up. This method is chosen as it provides a structured procedure to develop a framework of outcomes from the empirical data.

In order to get familiar with the data, all transcripts are re-read after conducting the last interview. During that phase, codes are given to meaningful sentences. Subsequently, each code is named with a theme. The themes are then grouped into one of the subsystems. At that time, the themes are reviewed, re-defined and re-named - resulting in patterns of meaning. Lastly, within the patterns of meaning in each subsystem, barriers and enablers are highlighted. This process allows for writing up an elaborate description of the perceptions, barriers and enablers per subsystem. In order to compare the data for synthesis a framework is developed for the focus group and the interviews similar to the framework for the literature review. This framework summarizes the barriers and enablers per subsystem. This research used the Atlas.ti software for thematic analysis. Appendix D elaborates on the process of thematic analysis.

Phase 5: synthesis

The synthesis is an interpretive process. It is done subsequent to the various data collection methods: the literature review, focus group and interviews. In order to explore the sense of the data in relation to each other, flexible pattern matching is used for analysis. Charef et al. (2021) have applied pattern matching in their research for an approach to achieve circular economy. They applied the pattern matching approach to compare the data collected through interviews (empirical) with data found in the literature (theoretical) - in line with the methodology of this research. They show that

combining systems thinking with pattern-matching can increase trustworthiness. They argue that this could lack in qualitative research (Charef et al., 2021: 3). Moreover, it increases internal validity of the research.

The flexible pattern matching approach is offered by Bouncken et al. (2021:255) as an 'iterative matching between theoretical patterns derived from the literature and observed patterns emerging from empirical data'. They argue for a process of simultaneous data collection and analysis, to take advantage of flexible data collection according to patterns that are found during the analysis. This iterative process is followed in this research, where the empirical data is used to validate the issues in the real-life context. The pattern-matching approach is based on finding differences and overlap in the themes. In this thesis the focus is solely on finding the overlap between the themes. Accordingly, a practical tool could be developed to support the actors in the socio-technical system.

4.5 Ethical considerations

This study collects primary data from many respondents and participants. Therefore, it is important to dedicate a section to the ethical considerations concerned with the empirical data collection. The researcher has an ethical responsibility in data collection and handling. Empirical data collection in qualitative studies generally appears with a smaller number of participants than quantitative studies. Therefore, it is harder to maintain anonymity and confidentiality (Moriarty, 2011). Furthermore, the majority of the interviews is conducted online and recorded on video: convenient for the researcher, but even more important to consider issues of anonymity and ownership, as Schuck and Kearney (2006) argue during the rise of new technology. This results in the necessity to formulate specific ethical guidelines of the interviews, including transparency about how the data is analyzed, saved and managed.

First of all, all participants are well informed about the study background, the research goal, the purpose of the interviews and the organizations that have a stake in the study. Subsequently, the participants are demanded to give consent to ascertain willingness to cooperate in the research and for confirmation of empirical data handling and analysis. The researcher asks for consent prior and after the interview. Moreover, the guidelines include that the recordings and transcripts from the participants will be removed by the researcher one month after the study is handed in.

5. Analysis of actors, values and processes

In the introduction of this thesis it is stated that the transition to a circular construction system has started, but that the current Dutch housing construction system is still largely embedded in a linear system. CCB requires a different way of working for the actors in the system. This chapter sets out to better understand how the actors are involved in the housing construction system, and how this linear system could become a circular system. The chapter answers the first sub-research question: *Which actors, values and processes are present in the internal system of present-day housing construction, and what are the opportunities for CCB in this system?* The results of this chapter come forth from desk research.

This chapter analyzes the actors (5.1), values (5.2) and processes (5.3) of traditional housing construction, following the definitions of actors, values and processes from the conceptual framework by Iacovidou et al. (2021). Furthermore, the analysis includes a section on the opportunities for CCB (5.4), as the impacts of the traditional system imply a radical change in the way of working.

5.1 Actors

In this research, actors are all individuals, parties or organizations who are involved in the internal system, and directly or indirectly influence the movement and processing of resource flows. They are driven by their interests and socio-economic, political and technical processes. There are a variety of public and private actors active in area development - and accordingly in housing construction. This section provides an overview of the key actors included in the process of housing construction, aiming to illustrate the power and agency of the actors as well as the interplay between the actor groups. The actors in this section are also the key actors involved in this research.

5.1.1 Municipalities

Municipalities in the Netherlands follow a land policy. The general aim of this policy is to ensure that land is available in sufficient quantities and on time (Rijksoverheid, 2022c). Due to an ever-changing society and climate, the layout of the environment has to be adjusted regularly. Municipal land companies play a crucial role in the supply of housing sites. The municipalities own or buy land to parcel for housing development, and they use the available instruments via the land policy (Platform31, 2019). PBL (2018) points out how municipalities own 38% of the built land in 2018. Land ownership is important in area development, as ownership allows for decisively steering the development. Subsequently, the land that is appointed for housing construction is tendered to project developers or developing clients to realize housing.

Each municipality has their own ambitions. Currently, they mainly aim to accelerate housing production, but they also have sustainable and social ambitions. A study by VerDuS (Connecting Sustainable Cities) based on qualitative case studies and quantitative survey results in the Netherlands, shows that sixty percent of the municipalities indicate that they have the objective of accelerating housing production. Nonetheless, they signify that even though taking many measures to accelerate housing production, there is lack of materials and manpower amongst private parties (developers, contractors and suppliers) (Platform31, 2019). Hence, they identify construction capacity as a point of concern.

5.1.2 Project developers

Project developers can buy land to develop lucrative (housing) projects, in which they capitalize on eventually selling the houses to consumers (non-business parties), housing corporations or investors (business parties). Heurkens and Hobma (2014) illustrate that when the land is owned by the municipality, project developers could participate in a tender, and be selected to develop in a certain location. Alternatively, land could be acquired via private landowners or there are sites available with opportunities for redevelopment. Accordingly, an agreement is signed between the land owner and the project developer. The project development involves various disciplines and other actors: architects, contractors, lawyers, planners and bankers. Each actor has their role and interests in this process. The project developer oversees the process and coordinates the actors (Bulloch & Sullivan, 2010). Project developers are bound to the tender requirements, as well as the land policy of the land owner, national regulations and local ordinances. Heurkens and Hobma (2014) show that most project developers see the spatial guidelines and local regulations by public actors as directive, rather detailed and inflexible. This gives developers few opportunities to develop according to market needs, but simultaneously this creates certainty for developers to respond to with their development plans. On the other hand, project developers have a critical role and a certain power as their capacity and willingness to develop is at stake in the acceleration of housing production. Therefore, the NEPROM (Dutch Association of Project Development Companies) argues for a number of measures for the new cabinet to implement in order to commit project developers to increasing housing production (NEPROM, 2017). In due course, the project developer should apply for the required permits, and when these have been granted - the developer could start. In order to minimize financial risks, the developer often already secures a purchase agreement with a consumer, housing corporation or (institutional) investors before or shortly after the start of construction. An article by Heurkens (2015) argues that ‘only developers who finance responsibly, collaborate with end users, act transparently, develop sustainably and show empathy with public goals will survive.’ They illustrate how this has led to various innovations within the

industry, adopting co-creation methods as well as focusing on sustainable development with new concepts and partnerships.

5.1.3 Architects

Burr & Jones (2010) illustrate that the role of the architect is not limited to developing design plans that are required for the permits. Their work often also includes practical guidance in the construction process, as an (independent) advisor. An architect is able to advise on design and material choices and could help request and compare construction quotations, based on the zoning plan. Furthermore, they are aware of the legal and regulatory provisions that apply to the construction and layout of the building. Architects check the quality of the work, and if the work is carried out in accordance with the plans, specifications and regulatory framework. Architects generally need institutional parties (including municipalities, developers, investors), land and capital to realize their designs, and on the other hand, developers need architects to translate their demands into designs. This shows a form of complementarity. Architects play a pivotal role in translating wishes of individuals, business partners and collectives into designs. According to Heurkens (2015), they have a key position in driving innovation in the industry, but when necessary they should adopt a more enterprising attitude focusing on business plans, financing and feasibility of designs.

5.1.4 Contractors and suppliers

Subsequently to the granted permits and the design phase, various contractors, subcontractors and other specialists are employed in the design and construction process for housing projects. Wamelink et al. (2010) show that contractors could be involved in an advising, collaborative or only executive role. In the traditional construction process, a distinction is made between designing and constructing - where the contractors focus on constructing. Yet, the contractors could also be involved in earlier stages of development by delivering construction requirements and specifications to the architect. contractors need suppliers in order to succeed in their construction process. Wamelink et al. (2010) explain how large contractors generally have multiple subcontracts with suppliers in order to have more flexibility. Contractors make agreements with suppliers, in which they provide a service, material or full product to the contractor. Suppliers generally have more specific expertise than contractors, for instance specifically on roofs or window frames.

5.1.5 Housing corporations

Housing corporations manage 2.4 million rental homes, occupying about a third of the Dutch housing stock. Traditionally, the core task of housing corporations is to provide sufficient and affordable housing for people (Aedes, n.d.). Early 1990s, a large-scale

privatization of municipal housing corporations took place. A large number of homes, formerly owned by the municipality, has been transferred to housing corporations. However, the Housing Act has been revised in 2015, encouraging housing corporations to focus more specifically on their core task of housing people with lower incomes. This puts an end to the two decades of broadening the activiteit after the privatization of housing corporations (Gruis, 2018). Gruis (2018) illustrates how, until 2015, the share of more expensive rental homes in the housing corporation stock increased structurally, but since 2016 the share of affordable housing increased. He argues in his essay that housing corporations' new-build plans are increasingly focused on the affordable housing segment. This is becoming a priority again. In order to realize more new-build, corporations often engage in partnerships with commercial parties, such as project developers (Aedes, 2020). Housing corporations can buy building plots from land owners (e.g. municipality) and partner up with a project developer to realize a project that fits the zoning plan. The other way around, project developers could also sell their projects to housing corporations. Aedes (2020) argues how housing corporations consider (rental) housing properties increasingly as an asset with a desired financial, social and technical return. It is their goal to be up to date on the latest sustainability requirements, flexible living concepts, innovation at construction companies and new construction assignments - in order to weigh best investment choices based on recent innovations. Nonetheless, limits on investment and priority on realizing a certain number of dwellings limits possibilities to invest in innovation and higher sustainability ambitions.

5.1.6 (Institutional) Investors

(Institutional) investors account for more than 10 percent of housing production each year. Besides commercial investors, there are institutional investors who invest in real estate. Commercial investors are defined as private persons or companies investing in real estate, whereas institutional investors are organizations that invest in real estate for their main mission; generating future income for pensions or insurance companies. IVBN, the representative of institutional investors, explains that modern housing is considered a sustainable investment and provides a reliable return with low risk profiles (IVBN, 2022). They argue mainly for the role of institutional investors in the mid-market rental sector, as there is great shortage of this housing type and housing corporations mainly focus on the social rental sector- as derived from their core task. Hence, they argue, housing corporations and institutional investors are complementary to each other. The investors play a key role in housing development with their institutional capital to invest in (rental) housing. They are profit-driven, aiming for return on investment. Yet, besides free-market, various investors are willing to invest in the mid-market segment, contributing to more affordable housing. (IVBN, 2018). This relates to their willingness to create 'societal value', as they invest money from

citizens via their pension or insurance. Besides, sustainability is highly institutionalized as financiers prioritize investors with high sustainability ratings, for instance according to GRESB (Christensen et al., 2022). Hence, institutional investors generally have social and sustainability goals.

5.2 Values

Values refer to the positive and negative impacts in the environmental, economic, social and technical domain. Hence, values are not about underlying reasons in the context of the conceptual framework, but rather about generating impact. The values provide insight into the cause and effect relationships of the internal system. Geissdoerfer et al. (2017) stress that a growing number of businesses understand that the current linear model increasingly exposes them to risks. These are environmental risks related to the earth's life-support systems, societal issues and vulnerability and economic risks related to supply, price volatility and market instability. This section further elaborates on the impacts in these domains.

5.2.1 Environmental domain

In past decades, cities have focused on improvements in better liveability and energy efficiency in buildings, but the current take-make-dispose system results in extensive amounts of consumption of resources, waste and emissions. Terrestrial carbon pools are depleted and the carbon level in the atmosphere is rising (Churkina et al., 2020). There are growing concerns worldwide about the situation of the local and global environment. Activities that are harmful for the environment vary per industry, yet it is widely recognized that the built environment is an enormous contributor to greenhouse gas emissions and material waste. Besides the current linear system, this is due to the use of mainly mineral-based construction materials like masonry, steel, concrete and composite (Churkina et al., 2020). The building sector accounts for 40-50% of global carbon dioxide emissions and solely the material use is accounting for 11% (Khasreen et al., 2009; Circulaire Bouweconomie, 2022). Substantial data on the specific environmental impact of residential buildings is not available. Nevertheless, Khasreen et al. (2009) explored the statistics of the UK department of Environment, Food and Rural Affairs, finding that homes in the UK are responsible for the consumption of 40% of primary energy in the country - including both construction and occupation. In the Netherlands, buildings are responsible for 25% of CO2 emissions in the current linear construction system. Furthermore, the Netherlands' construction and demolition activities result in 24 million tonnes of waste and Metabolic argues how this is a similar amount to a combination between consumer and industrial waste. Important to mention here is that 94% of this waste is recycled, but generally downcycled (Metabolic, 2017). De Klijn-Chevalerias & Javed (2017) show that there are not solely emissions during the construction phase, but

buildings have an embodied environmental impact during their life-cycle. This can be illustrated with energy. Firstly, energy is spent on material production for construction. During construction this energy is invested in installations, construction and transportation processes. Secondly, energy is consumed for the operation of the buildings - lighting, heating, ventilation, air-conditioning and more. Lastly, the energy captured in the buildings is released in the end-of-life phase when buildings are demolished. The total amount of energy that is consumed through these phases is largely dependent on context, building type and location.

5.2.2 Economic domain

In 2013, Manchini et al. (2013) already illustrated the increasing trend of the prices of raw materials and the price volatility between 2005-2009. Currently, geopolitical instability, depletion of natural resources and the COVID-19 crisis have led to rapidly increasing material prices and scarcity due to delivery problems (Jędrzejczak et al., 2021). This also accounts for the materials required for traditional housing construction processes. The significant effects in the cost increase of building materials result in an increasing risk for contractors and suppliers in their construction costs. Further, it jeopardizes housing affordability affecting various other actors in housing construction including the developer, client and resident.

5.2.3 Social domain

Geels (2005) argues for housing as a societal function fulfilled by a socio-technical system. Housing could be conceptualized in various ways, but this thesis adopts the conceptualization of housing in a societal context. Housing is increasingly viewed as a commodity, but it is more than solely infrastructure or a utility functioning in service to the economy. This study follows the argument of Mulroy & Ewalt (1996) that housing has a unique economic, psychological and symbolic significance. They argue that housing has a considerable impact on quality of life, with a house as a key that opens the door to meeting other basic needs. Hence, housing construction positively impacts the social domain by providing basic needs to society. As discussed in section 1.3, the impact on the social domain is positive if safe, non-transient and affordable housing is provided to society.

Secondly, as discussed in section 2.1, housing is a socio-technical system that is created and (re)produced by a variety of interacting actors. Geels (2005) argues how each actor has their own interests, resources and strategies to protect these. This results in power relations, argue Iacovidou et al. (2021). Hence, the processes of housing construction also have an impact in the social domain related to the actors in the internal socio-technical system of housing construction.

5.2.4 Technical domain

Lastly, physical flows of materials and energy impact the technical domain in the short-term and in the long term (Iacovidou et al., 2021). Each phase of the traditional process - construction, use, maintenance, demolition - requires certain technical knowledge on how to apply and process materials and energy. For instance, Vieira & Horvath (2008) show how it is technically challenging to deal with the end-of-life of buildings as they have many materials, products and equipment involved. Transfering elements of buildings to landfill at the end of their lifespan requires appropriate infrastructure. Besides, there is currently a growing demand for techniques to recover energy or materials from buildings (Vieira & Horvath, 2008). This impacts the technical domain. This is related to the impacts of traditional construction in the environmental and economic domain.

5.3 Processes

Processes are the resource flows from production, to consumption, to end of life management. This section elaborates on the process of area development in the Netherlands illustrating the traditional processes for housing construction. The section includes the key actors as discussed in the previous section.

Area development	Initiative	Feasibility			Realization	Management
		Definition	Design	Preparation		
Planning products	Structural vision/ environmental impact report	Area structural vision	Zoning plan / environmental impact report		Environmental permit for construction	
Research	*Quickscan environmental aspects * Planmer	(environmental) research / environmental impact report			Research for submission requirements	

Figure 4 *The process of area development. Adopted from InfoMil (2021).*

Figure 4 is adopted from knowledge center InfoMil (2021). They have conceptualized the process of area development towards housing construction. Generally, the four phases of area development are: initiative, feasibility, realization and management. The first phase, *initiative*, is intended to investigate whether area development is desirable in a certain location, or that there are better alternatives. It outlines the basic principles for the development. A central actor in this phase is the municipality. If they decide that housing construction is desirable on the land they start a tendering process to find a project developer or consortium for the housing construction process.

The second phase, *feasibility,* is perceived as the most intensive and complex phase. This phase consists of three sub-phases: definition, design and preparation. In this phase an urban design is developed. The designated project developer and architect play a central role in this phase. A zoning plan can be drawn up parallel to the drafting of the urban design. A good time to start with the zoning plan is as soon as the preliminary design is ready. The programmatic principles are included in the zoning plan. Subsequently, the project developer will then prepare the realization of the design, based on architectural designs and preparation of the application for the 'omgevingsvergunning' (environmental permit).

In the third phase, *realization,* the urban design is implemented as determined during the feasibility phase. The design and construction plan is executed by contractors and subcontractors. Since the industrial revolution, buildings have been mainly constructed from concrete, steel, fuel and raw materials extracted from the earth (Churkina et al., 2020). This follows a 'take-make-dispose' pattern. Such a pattern is characteristic of a linear model of resource consumption.

The *management* phase is aimed at maintaining and monitoring the development. Eventually, the constructed houses are sold either directly to a resident, or to a housing corporation or (institutional) investor. A corporation or investor retains the houses as assets in their portfolio. At a certain point the houses are either demolished or renovated. The article by Brinksma (2017) explains that a house has three lifespans: functional, economic and technical. The functional lifespan is usually the shortest and the technical lifespan the longest (Brinksma, 2017). The exact lifespan of a house cannot be predicted. Yet, in the current system houses often do not reach their technical lifespan due to a different functional or economic lifespan.

5.4 Opportunities for CCB in housing construction

The previous sections on actors, values and processes are set out to understand the traditional process of housing construction in the Netherlands. Nonetheless, the purpose of this study is to elaborate on the opportunities for an alternative process of housing construction. 'The circular economy' has gained large attention over the last period of time as a model that is able to decouple economic revenue from material input. The model of circular economy changes economic logic as it replaces production with sufficiency (Stahel, 2016). Products should be designed for reuse or disassembly for refurbishment, materials that cannot be reused should be recycled, what is broken should be repaired and what cannot be repaired should be remanufactured (MacArthur, 2013; Stahel, 2016). This idea is captured in various 'R frameworks'. These frameworks are used by academia and practitioners. They are

perceived as the ‘how-to’ of circular economy, capturing the core principles (Kirchher et al., 2017). Kirchher et al. (2017) present the 10R framework as the most nuanced framework on circular economy. This framework is shown in figure 5. The 10Rs are grouped in three sections - smarter product use and manufacture, extended lifespan of product and its parts, useful application of materials. These sections are respectively placed on an axis of ‘increasing circularity’. Each section contains various strategies to achieve a form of circularity.

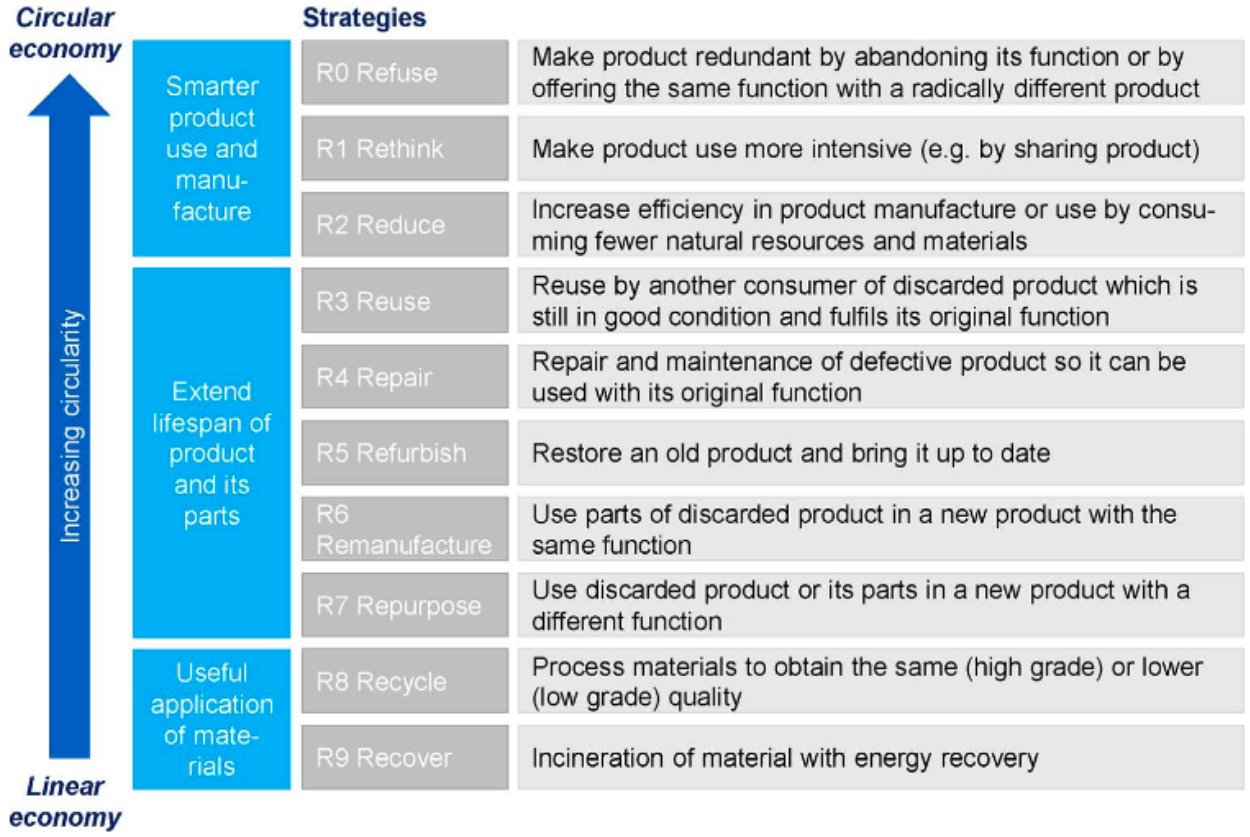


Figure 5 *The 10 Rs of the circular economy. Adopted from Kirchher et al. (2017: 224)*

Acharya et al. (2018) argues that adopting a circular approach in a high-growth and high-waste sector like the built environment generates large opportunities for businesses, governments and cities to minimize structural waste and realize more value from built environment assets. They have developed three principles for a circular approach in the built environment: 1) designing out waste and pollutant emissions, 2) keeping products and materials in use, and 3) regenerating natural systems. According to their research, implementing these principles in the built environment through partnerships and technological and business model innovation leads to reduced industry costs and less negative environmental impact. Furthermore,

it contributes to liveable, productive and convenient urban areas (Acharya et al., 2018).

Figure 6 is adopted from Churkina et al. (2020). Their article elaborates on regenerating natural systems. Their study focuses on the opportunities for a circular built environment where biobased materials serve as a carbon sink. The figure shows the transition towards a biobased built environment. It illustrates the interplay between the atmospheric and terrestrial carbon level and the built environment. The carbon pool on land was formed million years ago. Since then, the terrestrial carbon level increased and the atmospheric carbon level slowly decreased through natural processes. However, since the industrial revolution the terrestrial carbon pool is depleting and the atmospheric carbon level rapidly rises. This could partly be explained by the use of masonry, concrete, steel and composite in the built environment. The right panel shows the opportunities for a future with biobased materials like bamboo and timber - storing the carbon in these pools to replenish terrestrial carbon and reducing the carbon levels in the atmosphere, as supported by Sharma et al. (2014) and Van Dam et al., (2018).

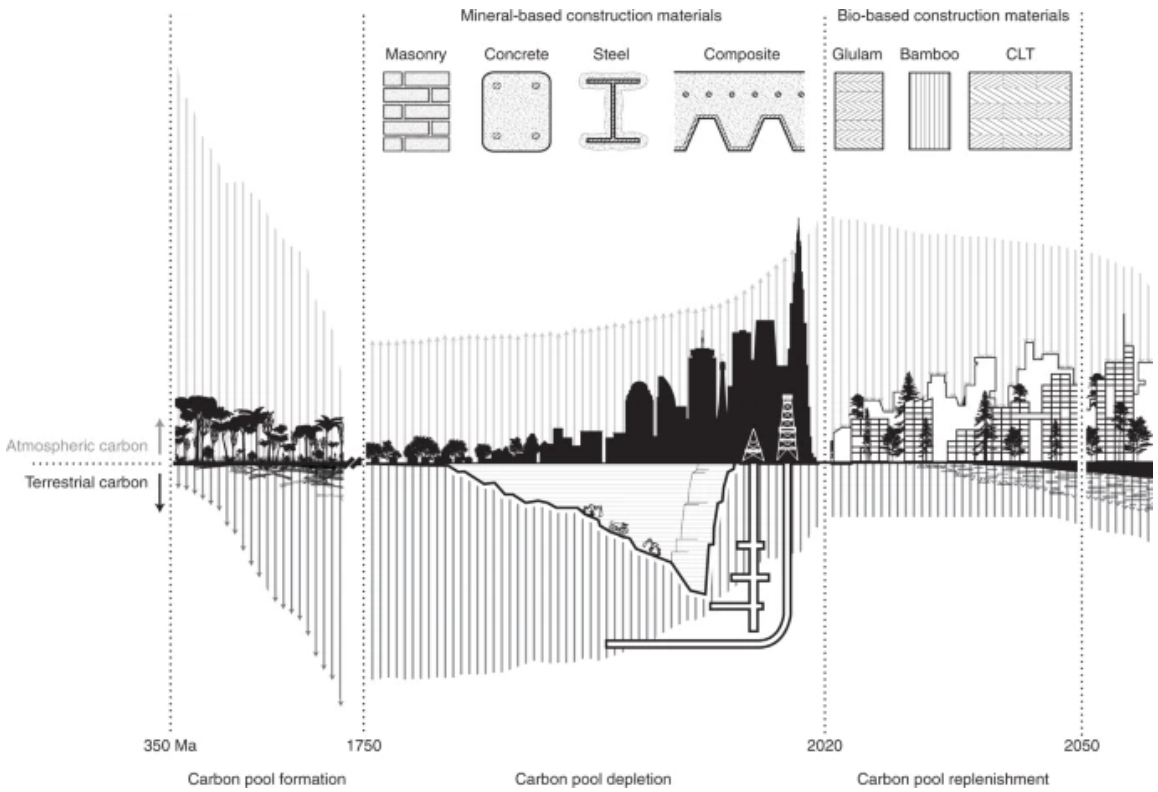


Figure 6 *The relation between carbon pools and the built environment. Adopted from Churkina et al. (2020: 270)*

Awareness of the valuable opportunities for a circular built environment is growing. Multiple frameworks are developed incorporating principles and philosophies in line

with a circular approach. Yet, translating these principles into practices requires a thorough understanding of the context of the built environment, and how its stakeholders could transition towards such a circular system. Hart et al. (2019: 619) explain how the constituting elements (incorporating buildings and infrastructure) are characterized by “long lifespans, numerous stakeholders and hundreds of components and ancillary materials that interact dynamically in space and time”.

5.5 Results from desk research

The analysis of actors, values and processes in traditional housing construction leads to an illustration of the traditional internal system. This system (figure 8) shows the linear process - from land, to housing, to end of life. Further, it shows the position of the actors in relation to each other. Moreover, this chapter has resulted in insights into opportunities for CCB in housing construction. Accordingly, an illustration of a potential circular system is developed (figure 9). The 10R framework by Kirchher et al. (2017) is integrated in this system.

Both outcomes, figure 8 and 9, offer a context-specific interpretation of the internal system of the conceptual framework. They are used to illustrate the internal system of housing construction in the following phases of the research. They are referred to as respectively the *linear housing construction chain* (figure 7) and the *circular housing construction chain* (figure 8). Both illustrations are a simplified representation of reality, since the interplay between actors, values and processes is continuously complex.

The circular housing construction chain does not include an ‘end-of-life’, but rather an ‘end-of-function’. At the end-of-function, the building or the elements (2D or 3D) are reused, refurbished, remanufactured or - reaching lowest value - recycled. This results in different (financial) value streams to various actors in the construction system. Therefore, actors in the system should work from a circular business model and build a circular business case. Accordingly, they could account for a stake in the residual value of buildings or elements. Furthermore, this system requires a different way of thinking in early design and development stages. A circular system focuses on smarter product and material use, ‘design for disassembly’ and a circular business case. This is captured in the illustration as ‘R1 Rethink’ and ‘R2 Reduce’. ‘R1 Rethink’ already starts at the land owner, since the eventual area development is based on the land allocation and policy by the municipality.

Figure 7 *The linear housing construction chain. Author's own work.*

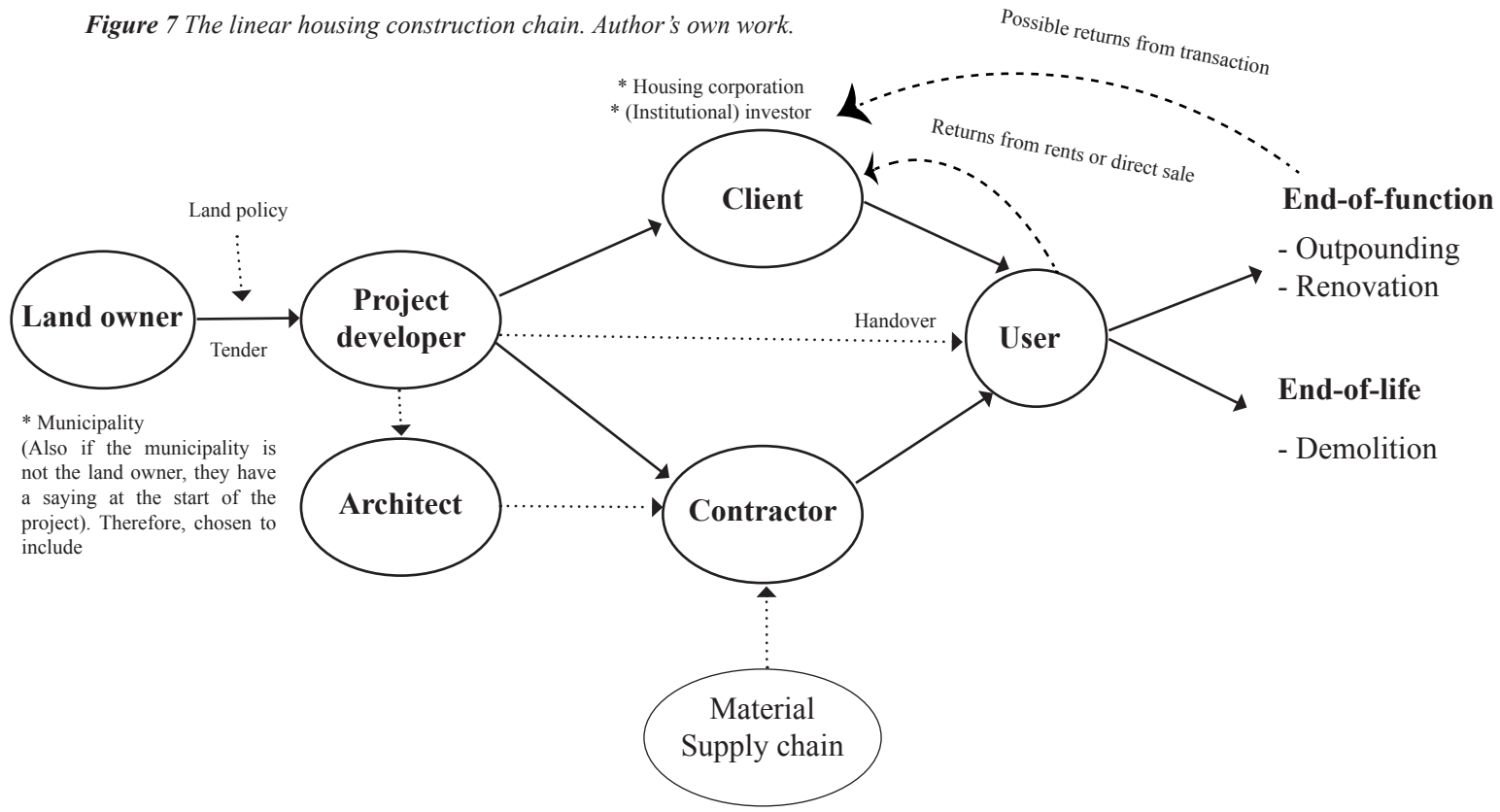
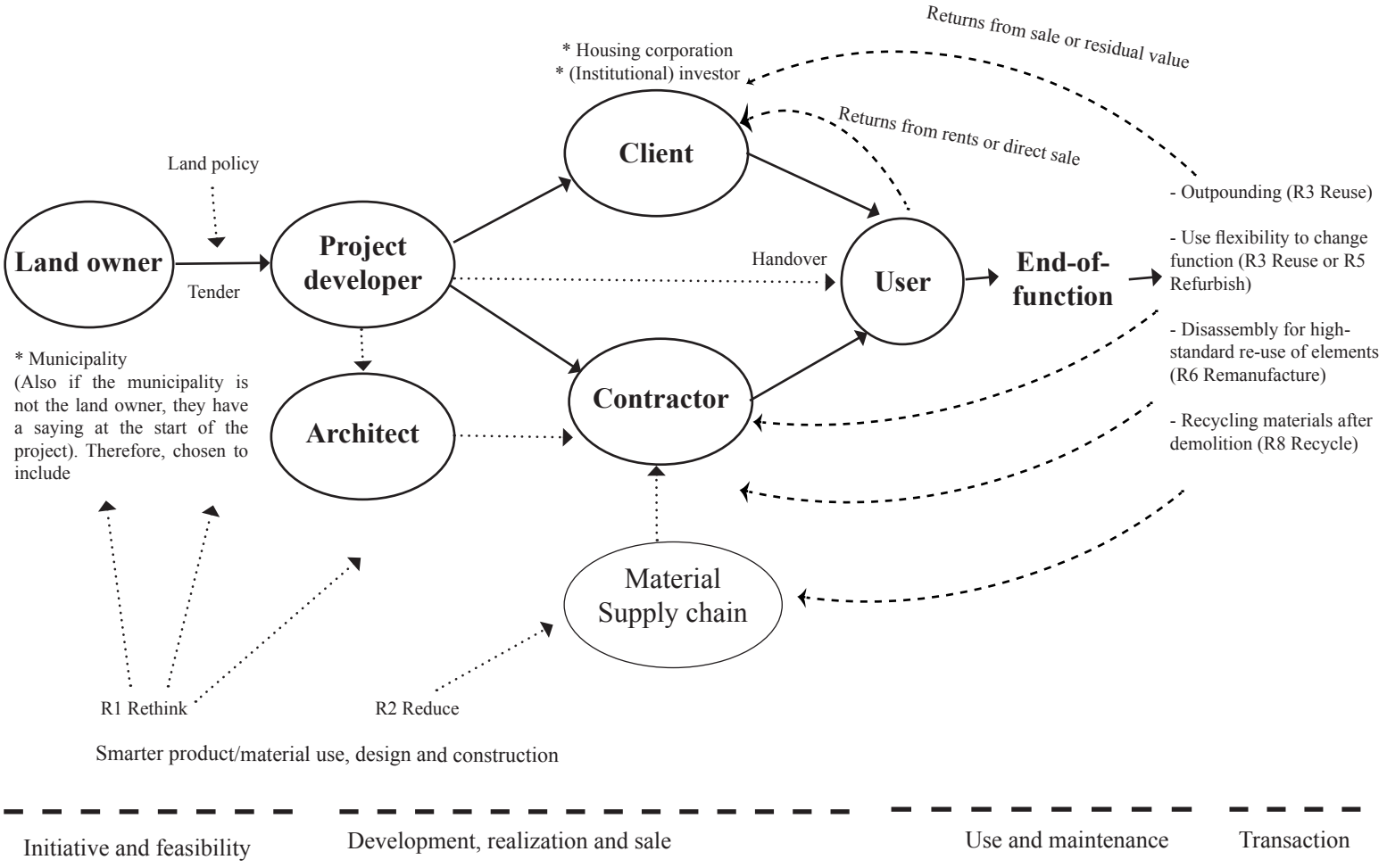


Figure 8 *The circular housing construction chain. Author's own work.*



5.6 Conclusion

This chapter captures the actors, values and processes present in the internal system of present-day housing construction. Besides, this desk research is used to do a first exploration of the opportunities for CCB. This chapter had the purpose of answering the first subquestion: *Which actors, values and processes are present in the internal system of present-day housing construction, and what are the opportunities for CCB in this system?*

First of all, the chapter discussed a variety of public and private actors in present-day housing construction. These are municipalities, project developers, architects, contractors and suppliers, housing corporations and (institutional) investors. Each actor has their own interests, power and role in housing construction and furthermore, there is an interplay between the actors. Secondly, the values are discussed. These are the positive and negative impacts in the environmental, economic, social and technical domain. These values show that housing is a basic need in a societal context. Besides, a growing number of individuals and businesses understand that the current linear system increasingly exposes them to environmental, social and economic risks; they need to consider the impact on these domains as well as the role of the technical domain in the transition to a circular system. Hence, there should be common interests amongst the actors to switch to circular construction processes. Circular processes allow for value in the various domains. This results from the implementation of the R principles. Here, positive environmental value is crucial to achieve the climate targets. Thirdly, the traditional process of area development and housing construction is explained, discussing how four phases (initiative, feasibility, realization and management) lead to housing construction. The traditional system follows a linear take-make-use-dispose pattern.

The outcomes of the desk research are a ‘traditional’ linear housing construction chain and a circular housing construction chain. The housing construction chain serves as an extension of the conceptual framework: a context-specific interpretation of the internal system. The linear and circular housing construction chain are respectively used to understand the current situation and to illustrate the goal of the transition to a circular system.

6. Literature review on barriers and enablers for a circular system in the built environment

Besides the desk research to better understand the actors, values and processes in present-day housing construction, academic and practitioner literature over the past ten years is reviewed on transitioning to a circular construction system in the built environment. Before conducting empirical data collection it is beneficial to get familiar with the barriers and enablers that are identified up to now by researchers and practitioners in the construction industry. This chapter sets out to answer the second sub-research question: *Which barriers and enablers are identified in the literature for transitioning to a circular system based on CCB in the built environment?*

This chapter consists of three sections. The first section (6.1) discusses starting points for the literature review, based on another literature review of barriers and enablers for a circular economy in the built environment. The following section (6.2) analyzes the barriers and enablers per subsystem that are identified in the literature review. Finally, the last section (6.3) presents the chapter conclusion.

6.1 Starting points for the literature review

There is a growing body of literature that recognises the need to transition to a circular construction system in the built environment. Nonetheless, few studies report specifically on circularity in the housing construction sector. Hart et al. (2019) have conducted a literature review on barriers and enablers for a circular economy in which they focus on the case of the built environment. They have done relevant research on barriers and enablers for a circular economy in the literature. Various outcomes from their study are derived as a starting point for the review in this study. They illustrate how academic literature focuses mostly on either systematic review of case studies for barriers and enablers, whereas industry papers draw lessons on specific cases or develop manifestos for the circular economy - mentioning many barriers and enablers. Furthermore, Hart et al. (2019) raise the issue of subjectivity. The frequency of an identified barrier does not directly correlate with its importance. Barriers and enablers are context and stakeholder specific. They are related to different representatives, built environment scales and types of businesses or organizations (Hart et al., 2019). This notion of subjectivity is important to take into account.

Table 2 *Barriers and enablers per subsystem from literature review. Author's own work.*

Internal

System actors

Barriers	*Enablers*
* The problem of the continuity of actors across a building's life cycle	* Collaboration within the supply chain (where all partners commit to pre-defined circularity goals in order to obtain the intended profit. That way, a model of shared risks is created)
* The construction industry thinks in the short term, while clients often maintain long-term thinking	* Sharing knowledge and experiences (best practices, lessons, results from case studies)
* Lack of circular economy skills by employees in the supply chain	* all chain partners having the right preconditions and perspective for action, to be able to fulfill their role
* Fragmented definition of circular economy	
* Lack of interest amongst the chain actors as traditional methods are stable	

System values

Barriers	*Enablers*
* The realization costs for timber construction higher than traditional construction	* The value of sustainable buildings will increase over time, as a result of legislation, demand by investors and increasing resource scarcity
	* Cost-neutrality in both investment and operation period in comparison to non-circular housing construction projects (allows for replicability)
	* Opportunities for low exploitation costs through passive energy solutions and healthy living environment (allows for higher investment opportunities)
	* Shorter production time results in higher financial rendement (quickly to use-phase)

System processes

Barriers	*Enablers*
* Fragmented structure of supply chain and construction industry	* Circular economy principle of systems thinking: identifying synergies and divergences
* Complexity of buildings	* Living lab as a testing ground for circular construction concepts for grip on innovation processes prior to changing regulation
* Loss of ownership	* Phasing of construction projects, with KPIs and evaluation moments per phase
* Lack of incentive to design for end-of-life	
* Lack of consideration of end-of-life issues	
* The Dutch construction sector is project oriented and is challenged through tender processes	
* A shortage of knowledge of how the design of buildings, components and products can affect their circularity	

External

(Natural) resources and provisioning services

Barriers	*Enablers*
* Timber for biobased construction has to be imported from other (near) countries resulting in high material price	

Technology, infrastructure and innovation level

Barriers	*Enablers*
	* Information sharing capabilities (e.g. BIM) * Material passports * Development of enabling technologies to recover materials and take-back schemes * Design tools and guidance for disassembly and flexibility * Database for circular products and materials including knowledge and experiences from various parties * Standard system of KPIs for measuring circularity in supply chain * Development and co-creation of disassemblable building products

Governance, regulatory framework and political landscape

Barriers	*Enablers*
* Legal definition of waste restricts specific subsequent use	* Knowledge sharing on what circular construction means and is also clear what the legal requirements are and to which the measuring instruments apply. * Collaboration through triple helix (public-private-third sector partnerships) and in consortia * Material passports * Taxation and subsidies as economic instruments * Multi-level policy integration is needed to alter value chains to enable a greater reduction in material inputs and changes in actor behaviour *Municipal policy themes on circularity/climate neutrality as a tool * Review and adjustment of the environmental performance of buildings (MPG) for a circular system * Specific requests through public tenders * Regulation 'CO2 levy industry' results in increase in the cost of concrete, while it has no effect on the cost price of biobased material (CLT)
* Lack of policy measures and inconsistent rules to provide incentives for all stakeholders	

Activities performed by business and the market

Barriers	*Enablers*
* Lack of market mechanisms for material recovery: well-recovered materials more expensive than virgin * Unclear financial/business case * Low value of materials and products at end-of-life * The misalignment between business planning cycles and built environment asset life-cycles * Boom (hoogconjunctuur) phase in the construction sector hinders long term collaboration	* Articulating the financial value aspects of the circular economy * Clear business case based on a circular business model * Development of higher value secondary markets * Leadership and first movers (e.g. The national government as a launching customer) * A valuation system in which residual value becomes an important component of the market value

Patterns of behavior relating to meeting human and societal neeeds

Barriers	*Enablers*
* Lack of interest amongst chain actors as traditional methods are stable * Conservative mindset	* Press attention as a stimulus * Awareness raising campaign

6.2 Analysis of barriers and enablers per subsystem

The literature review concerning the barriers and enablers for transitioning to a circular construction system in the built environment has identified and classified more than 50 barriers and enablers. These emerge from various references over the last ten years. Table 1 shows a framework with a clustered summary of the barriers and enablers in the subsystems of the conceptual framework. The extensive table of the literature review is included in appendix A. That table includes the various sources that are consulted. This section analyzes relevant insights of the overview of barriers and enablers per subsystem.

The outcomes of the literature review comprehend more enablers than barriers. This indicates a progressive mindset in the literature for transitioning to a circular construction system in the built environment. The focus is on the opportunities rather than the hurdles. It emerges from the summary in the table that the majority of the barriers are located within the internal system and the majority of enablers are identified in the external landscape. The barriers range from short-term thinking to complexity of the buildings to a shortage of knowledge on circularity for buildings. The internal system could benefit from chain collaboration where actors in the chain share responsibility and risks. Furthermore, knowledge sharing is an enabler. Several reviewed sources stress the importance of sharing experiences, best practices, lessons and results from case studies.

In both academic and practitioner literature, finance is seen as a barrier rather than an enabler. These barriers mainly have to do with an unclear business case for a circular system and the market mechanisms for material recovery while keeping the material value, related to the *activities performed by business and the market* external subsystem.

Remarkably, the majority of the enablers are identified in the external subsystem concerning *governance, regulatory framework and political landscape*. Something that occurs in various academic and practitioner sources, is the importance of knowledge sharing on circular construction and the related legal requirements and measuring instruments. Moreover, it is worth mentioning that barriers and enablers in the *natural resources and provisioning services* external subsystem have only been discussed in one of the reviewed sources. Additionally, having in mind the issue of subjectivity, the frequency does not imply a direct correlation with the importance. Accordingly, it is significant to further explore the barriers and enablers with empirical data specifically on housing construction in the built environment, as is reported on in the following chapters.

6.3 Conclusion

The literature review was undertaken to answer the second subquestion: *Which barriers and enablers are identified in the literature for transitioning to a circular system based on CCB in the built environment?* As explained in the methods section 4.2, the literature review takes into account literature on barriers and enablers for circular construction in the built environment, in- and outside the Netherlands. The scope is broadened as the - academic - literature on specifically housing construction is limited.

To conclude, the literature review has identified more enablers than barriers to transition to a circular system in the built environment. There are many barriers identified in the internal system and several other highlighted barriers are financially related. Chain collaboration and knowledge sharing seem important enablers in the internal system to transition to a circular system based on CCB. Besides, many enablers relate to external subsystems, predominantly the *governance, regulatory framework and political landscape* subsystem. Lastly, the *activities by business and the market* external subsystem could support the internal system by circular business models and a clear business case. The insights in barriers and enablers from the literature review are further explored with empirical research. Chapter 7 starts by presenting and analyzing the results from the focus group.

7. Identification of barriers and enablers from a focus group

In accordance with the data collection methods, the literature review follows up with empirical data collection. Firstly, empirical data is acquired with a focus group consisting of six participants from a project developer. The focus group sets out to explore if results from the desk research and literature can be validated or if other barriers or enablers appear in the present-day context. The barriers and enablers from the literature review serve as a starting point for discussion, but there is room to depart from these insights to further explore the barriers and enablers that the participants currently experience.

The focus group consists of various assignments with the participants. These assignments are further explained in appendix B. First of all, the housing construction chains developed in section 5.5 have been presented to the participants to validate or improve these chains. The participants have validated the housing construction chains during the session. They acknowledged the system approach and defining the internal system as the housing construction chain. Besides, they indicated that the illustration with opportunities for CCB was helpful in understanding the system. This has been a starting point for the rest of the focus group session and the interviews. This chapter contributes to answering the third sub-research question: "*How are barriers and enablers to accelerate the transition to a circular system currently experienced by project developers?"*

The structure of this chapter takes the form of five sections. The first section (7.1) shows the themes that have emerged during the thematic analysis. These themes are grouped per subsystem of the conceptual framework. The following section (7.2) provides the main insights of the discussions in the focus group. This section follows the themes that are identified in the thematic analysis. Accordingly, a section (7.3) is set out to present the results of the exploratory assignment where the participants placed sticky notes with barriers and enablers on a certain subsystem. The following section (7.4) shows an overview of the identified barriers and enablers per subsystem. The chapter ends with a conclusion (7.5).

7.1 Overview of themes from thematic analysis

The transcript of the focus group is coded by highlighting meaningful ideas, sentences or parts of discussions. These quotations are named with a theme. In the end there are various quotations within a theme. Accordingly, each theme is related to one of the

internal or external subsystems based on the definitions of these subsystems. This is shown in figure 9. The process of the thematic analysis is included in appendix D.

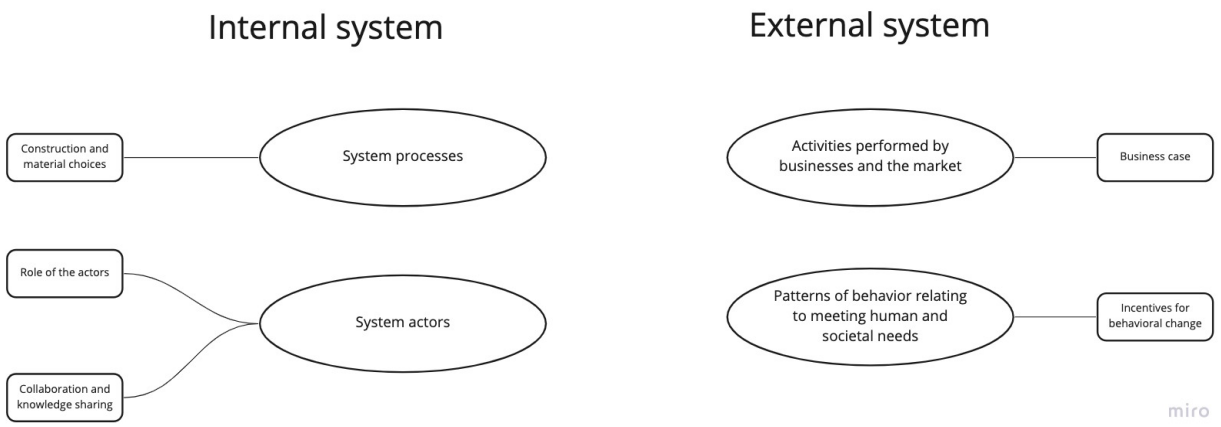


Figure 9 *Overview of themes per subsystem after focus group analysis. Author's own work.*

7.2 Insights from the discussions in the focus group

Section 7.1 shows how various themes emerge from the discussions during the focus group. These discussions result in various valuable insights. These insights are reviewed in this section. They are related to either the definitions of CCB, or to one of the subsystems covered in figure 9.

Defining circular and conceptual building

After the introduction of the research context the participants directly started discussing the definition of circularity in the context of circular and conceptual building. Fortunately, the first assignment concerned defining circular building and conceptual building in the context of housing construction. Each participant appears to have a slightly different view on the definitions, but hearing each other's view led to consensus in line with the working definition. Hence, it has been helpful to have working definitions prepared as a basis for the rest of the focus group. These working definitions are presented in section 4.1.

System processes

Construction and material choices

Discussing the definition of circular and conceptual building resulted in a discussion on construction and material choices for future housing. The idea of flexibility and design for disassembly resonates with the participants. One of them argues, "if you are building a house, you know that in 30 or 40 years it needs major maintenance. So it would be relevant to already think about how parts can be easily disassembled or replaced." Another participant adds that a product does not have to be at the end of its lifecycle to get a new function, but that flexibility allows for change of function over

time. This extends the functional lifespan of a house. For material choices, one of the participants highlights how he experiences the growing importance of embodied carbon in buildings. This overlaps with the energy transition. This requires replacing concrete and steel with biobased materials that store carbon, such as timber.

System actors

Role of the actors

During the other assignments there were various topics that produced consensus. One of these topics is that the transition to a circular system based on CCB is not particularly a technical challenge, but rather an organizational challenge where all actors in the housing construction chain fulfill a particular role that suits the circular system. Throughout the focus group various ideas on the role of actors in the chain arised.

Project developers are directly connected with the municipality and the majority of the participants are worried about the relation and mutual understanding between municipalities and market parties. Municipalities should develop tools to stimulate circular housing projects. One of the participants brought up, “Shouldn’t the municipality give a discount on the land for a circular housing project? It is a contribution to the climate targets.” However, there were contradicting opinions in the discussion on this specific idea. All participants agree that the municipality has a central role from the start of housing construction projects, yet another participant stresses that the business case for circular building should also be strong without interference from the municipality in the land prices. He states, “I think pointing to the municipality here is *old thinking*. Saying oh, the municipality makes the land expensive so our business case does not work. I think that as a company you just have to really stimulate yourself to get that business case strong. Otherwise it is pointing to the municipality 'you do that' and then there is no incentive to change yourself.”

Moreover, discussing the role of housing corporations, a participant that formerly worked for a housing corporation explains the role of a program of requirements (PoR) for corporations, “There is a design PoR and a technical PoR, and we work according to that. This also includes materialization and dismantling. And then we had a ‘prefered supplier chain’ with several contractors with whom we cooperated in construction to reduce costs and work efficiently.” The participants agree that housing corporations should make room for circularity in their PoR to stimulate other chain actors.

Furthermore, the participants expressed that they see a central position for the project developer in a circular system for housing construction, but they are struggling how to

fill in this role. One of the participants expresses, “as a developer you do not really have a ‘plus’ for circularity. You either do it for your customer, or you do it for the municipality and their climate targets. We are actually a conduit in this regard. So there should be an incentive for developers either on the side of the land costs or on the client side.” This relates to the problem of continuity of actors across a building’s life cycle: not all actors profit from circularity in the long term. Those actors include mainly developers, but also architects. However, another participant responds that it is also beneficial for a project developer to engage in circular projects, explore how to stay involved and gain returns from circularity. Another participant adds on this discussion that he increasingly experiences chain integration in housing construction. He argues that in this case, developers could become their own client as investors. This is beneficial for gaining from the value of circular concepts in the long term. All participants agree that it is interesting to explore how a developer could have a key position in the chain with knowledge on circular systems and how to incentivize other chain actors, “we as project developers do have the organizational power for that.”

Collaboration and knowledge sharing

There is consensus amongst all participants that there is a lack of collaboration and knowledge sharing in the chain. One of the participants stresses, “Now it is always: I have my exploitation, you have yours. And actors protect that. Then one party says: no, it is really that expensive, you really have to pay that. But there is no collaboration towards common goals.” One of the participants returns to the point of collaboration after a while, “I was triggered by your point on chain collaboration. It is quite outdated, how we are working now in the chain: passing on the baton every time to a next party. I think in a circular future we will have more of a round table idea, where all actors sit around the table and collaborate.” He believes this is required for other forms of materialization and different processes, where consultation with client, end user and architect becomes more fundamental.

Knowledge sharing is brought up as an important topic related to collaboration. Developers could have a directing role in the process, connecting all actors through communication at the start of a project. The participants believe that this could increase transparency and help to share knowledge and ambitions. Even though parties see the importance, there is a hesitant attitude on knowledge sharing amongst actors, “What you notice a lot is that knowledge sharing is difficult. That feels like making our competitor smarter.” Nonetheless, other participants express good experiences with sharing knowledge and ambitions with other actors, because it reduces unreliable assumptions. Besides knowledge sharing, another participant stresses the importance of sharing responsibilities in a project, “First, you share knowledge and you make agreements with each other. But you also enter a partnership together, where you each

provide capacity or money to reach the goals according to your own expertise. In a project I know, they used a *dynamic distribution model,* where all partners put their part of an agreed fee. If the KPIs (Key Performance Indicators) were met, all partners got a financial return. So there was a shared responsibility to make that happen, with a financial incentive." A certain financial incentive resonates with the other participants, confirming that they believe this leads to better collaboration.

Activities performed by business and the market

Business case

During the focus group, a strong business case for CCB is a recurring theme. Having participants from various roles and with different backgrounds, interesting discussions arise on the feasibility of these ideas. The following ideas resonated with the participants:

- Including the residual value of a house, elements or materials in the business case of investors or corporations so that they will profit from this in the long term.
- Changing land issuance by reintroducing a temporary issuance destination linked to the functional lifespan of a house. That leads to cheaper land costs. The elements of a circular concept on land with a temporary destination could be disassembled after 30 year.
- Chain integration where a developer will also be the investor. Having a stake in a house over the whole lifespan incentivizes the investor to take the lifecycle costs into account. The investor experiences the development of the value of a building and its elements. That could be a driving force for circularity.

Patterns of behavior relating to meeting human and societal needs

Incentives for behavioral change

Various participants expressed strong opinions on the role of the mindset and attitude of people towards circularity and climate targets. One of the participants stresses the importance of the acceptance of the end user, "Isn't the greatest acceptance ultimately in the end user? The awareness that they might have to pay more, their behavioral pattern?" This point evokes discussion, as other participants believe that the end user solely uses what the chain develops and that the responsibility should not be with the end user. However, the participant stresses that in the end, every actor in the chain is a user. Accordingly, discussion arises on incentives for behavioral change, "It also took a crisis to understand that health is very important. But when it is gone, everyone no longer cares. So how do you create something that stays with the awareness for a longer time? That people think: this is really for the long term, I am going to change my behavior?" She believes that a major climate crisis in the Netherlands might be required to change people's behavior on environmental choices. Another participant

argues that people will change their behavior if they understand the benefits, “That is what we see with solar panels. People increasingly understand that it leads to a lower energy bill. That leads to acceptance. If a circular product is beneficial for a consumer or user, they will adopt it.”

A collaboration model as main enabler

At the end of the final discussion, the participants were asked which topic - and related barriers and enablers - is currently most important for them in accelerating the transition to CCB. The participants believe that collaboration in the chain is the predominant enabler to accelerate the transition. Nonetheless, lack of collaboration is identified as a current barrier, and therefore the participants are still searching to make collaboration between chain actors more concrete. One of the participants stressed, “A model for collaboration would be valuable. To have a collaboration model based on trust. I think there is a perspective for action in it. But there is much more behind that, because you can include a lot in such a model. I think it is very solution-oriented to say: oh, we need to make a model! But I think that would give direction. And now we have to find out how we could do that, and what examples there are already.”

7.3 The exploratory assignment

Besides the results from the discussion, the participants used sticky notes to express their thoughts on barriers and enablers by placing the sticky notes in the system. The visual result is included in appendix B. In the assignments before the system exploration assignment the discussions were mainly concerning the system actors and processes in the housing construction chain, while touching upon business models and the broader sense of human and societal behavior. During the system exploration assignment the participants focused rather on placing the internal system actors, values and processes in the broader landscape with external subsystems. This has resulted in a wider exploration of barriers and enablers in the system.

For instance, a participant added ‘EU regulations on embodied carbon and taxonomy’ as an enabler related to the *governance, regulatory framework and political landscape* subsystem. Another participant added the ‘complexity of the material supply chain’ as a barrier related to the *natural resources and provisioning services* external subsystem. Due to time limitations, it was not possible to have discussion on each of the barriers and enablers on sticky notes. The barriers and enablers that have been elaborately discussed are included in section 7.1. Nonetheless, the other barriers and enablers are taken into account in the clustered summary of results in the next section. They serve as input for the interviews with other actors and stakeholders to further explore and possibly validate these insights.

Table 3 *Barriers and enablers per subsystem from the focus group. Author's own work.*

Internal

System actors

Barriers	*Enablers*
* The problem of the continuity of actors across a building's life cycle: not all actors profit from circularity in the long term (mainly developers and architects)	* Transparency between the actors during the development
* Bias and assumptions about other actors in the chain	* Each actor having a clear role and responsibility in projects
* Actors have an attitude of negotiation rather than cooperation	* Municipalities setting conditions for circularity when issuing a permit
	* Municipal (financial) tools to stimulate circular housing projects
	* Partnerships between actors
	* Chain integration for faster processes and more responsibility with that actor
	*Room for circularity in PoR of housing corporations and investors
	* Collaboration within the supply chain, following a 'round table' approach
	* Sharing knowledge and experiences
	* Stimuli between chain actors
	* Dynamic distrubition model with shared responsibility and KPIs on circularity

System values

Barriers	*Enablers*
	* Upscaling industrial building for lower investment costs/ economies of scale

System processes

Barriers	*Enablers*
* The processes are designed for traditional construction methods	* Starting processes from a partnership instead of a tender process
* Aesthetic quality of industrially produced houses	* Integrate flexibility in design to extent functional lifespan of a house
* A paradoxal task: financial returns --> affordability, linear system--> circularity	* Design for disassembly
	* System where supplieres are challenged to supply PAAS (Product - as - a - service)
	* Pilots/living labs with clear ambitions, KPIs and evaluation

External

(Natural) resources and provisioning services

Barriers	*Enablers*
* Complexity of material supply chain	
* Lack of transparency in material supply chain	

Technology, infrastructure and innovation level

Barriers	*Enablers*
* Lack of innovation in financial instruments	

Governance, regulatory framework and political landscape

Barriers	*Enablers*
* Lack of capacity in the regulatory framework	* EU Including embodied carbon in measuring building emissions
* A rigid relationship between the government and the market after tender processes	* EU Taxonomy for sustainable activities
* MPG lacks in weighing circularity factors	* Validate residual value for business models
	* Carbon credits and CO2 certificates

Activities performed by business and the market

Barriers	*Enablers*
* Higher costs on the short term threaten affordability	* Including residual value in business models
* Unclear financial/business case	* Assign value to environmental footprint
	* Upscale industrial building for economies of scale
	* Temporary land issuance with cheaper land costs (houses are disassembled after 30/50 years --> design for disassembly)
	*Chain integration where the developer is also investor and hence experiences the value development of a building and its elements

Patterns of behavior relating to meeting human and societal neeeds

Barriers	*Enablers*
* Difficulty of changing behavior over the longer term	* Crisis to raise and increase awareness
* Conservative mindset	* Co-creation on a larger scale
* Consumer, resident or user lacks awareness on CCB or sustainability and does not incentivize chain actors	* Make the end user ambassador of circular house
*Insecurity about CCB or change	

7.4 Analysis of barriers and enablers per subsystem

Table 2 shows the barriers and enablers per subsystem that result from the focus group. These include the barriers and enablers that are identified with thematic analysis from the discussion. Besides, the barriers and enablers from the sticky notes in the exploratory assignments are included. This section analyzes relevant insights of the overview of barriers and enablers per subsystem.

The majority of the barriers and enablers are related to the internal system, concerning the system actors, values and processes. The participants stress the importance of transparency, collaboration, partnerships and knowledge sharing as enablers to transition to a circular system. Currently, there are many assumptions about other chain actors and there is a mindset of negotiation rather than collaboration. This is experienced as a barrier. Furthermore, related to system processes, a barrier is that processes are designed for traditional construction methods. Enablers are processes that allow design for disassembly and flexibility.

There are multiple enablers identified related to the *activities performed by market and business* external subsystems relating to circular business models and a strong business case. This corresponds with the results from the literature review. In contrast to the literature review, the focus group identified several relevant barriers and enablers related to the *patterns of behavior relating to meeting human and societal needs* external subsystem, focusing on the difficulty of changing behavior, conservative mindsets and the opportunities for co-creation and long term behavioral change. Apparently, this is an essential topic for practitioners in the housing construction chain. Barriers and enablers related to this subsystem are further explored in the interviews.

The focus group has covered little barriers and enablers related to the *natural resources and provisioning services* subsystem. This is comparable to the literature review. The reason for this is not directly clear, but a possible explanation might be that the respondents are mainly focusing on the transactions between the key actors in the housing construction chain rather than acquiring the resources, as the material and resource supply chain has its own complexity. Hence, searching for an explanation, it could be a consequence of the deliberate choice to focus on the housing construction chain as the internal system.

Similarly, only one barrier is identified related to the *technology, infrastructure and innovation level* subsystem. It seems that stakeholders in the external landscape would mainly focus on this subsystem, rather than project developers as key actors in the housing construction chain. These external stakeholders would approach the transition

to circularity on a different, more overarching level and could focus on innovation and tools to help the system to transition. Nonetheless, this is solely a possible explanation that could be validated or rejected with the interviews.

7.5 Conclusion

Chapter 7 sets out to highlight and analyze the outcomes of the focus group with project developers. The aim was to answer the third subquestion: *How are barriers and enablers to accelerate the transition to a circular system currently experienced by project developers?*

At the start of the focus group the participants validated the linear and circular housing construction chain. Hence, this chain is a useful context-specific interpretation of the internal system of the conceptual framework and will be used in the further empirical exploration.

The focus group has resulted in various barriers and enablers that project developers with various functions and from diverse backgrounds experience in present-day accelerating the transition of CCB in housing construction. Where in the literature review the majority of the barriers and enablers is identified in the subsystems of the external landscape, the focus group predominantly results in barriers and enablers in the internal system - the housing construction chain.

From analyzing the focus group discussions it results that the transition to a circular system based on CCB in housing construction is not necessarily a technical challenge. It is rather an organizational challenge concerning the actors, values and processes in the housing construction chain. Collaboration between chain actors is experienced as the most important enabler. Hence, this gives more specific direction to what actors require to accelerate the transition to a circular system based on CCB. These important insights are taken into account for further exploration and possible validation in the interviews. Furthermore, there is a focus on the financial viability of CCB, highlighting the importance of a strong business case based on a circular approach. Likewise, this focus point is used as input for the interviews.

8. Identification of barriers and enablers from interviews

The second part of the empirical data collection consists of conducting thirteen interviews with actors in the Dutch housing construction chain, and stakeholders impacting the transition to CCB in housing construction. The goal of the interviews is to explore and validate which barriers and enablers are currently experienced by a wider range of respondents related to CCB in housing construction. A semi-structured approach has been adopted for the interviews. The barriers and enablers from the literature review and the focus group serve as input for the interviews. The following sub-research question is established for this chapter: *How are barriers and enablers to accelerate the transition to a circular system currently experienced by actors in the internal socio-technical system and stakeholders in the external landscape?*

This chapter begins by a section (8.1) presenting the results of the thematic analysis of the interviews, building upon the themes that have been identified in section 7.1. Subsequently, a section (8.2) elaborates on the responses from the interviews on the definitions of CCB, the internal system and the external system highlighting relevant insights. Accordingly, the identified barriers and enablers are clustered per subsystem and analyzed (8.3). The chapter ends with a conclusion that answers the fourth subquestion (8.4).

8.1 Overview of themes from thematic analysis

Similar to the transcript from the focus group discussion, the transcripts from the interviews are analyzed with the thematic analysis approach. The focus group has resulted in five main themes. The thematic analysis of the interviews builds upon the thematic analysis of the focus group. The number of themes has increased to 21 including the interview data, following the sub-headers of chapter 8.2. These themes are categorized under the subsystems of the conceptual framework. The result of the thematic analysis is shown in figure 10. It is important to mention that at this stage several themes are reviewed and renamed, following the fourth and fifth phase of thematic analysis by Braun & Clarke (2012) as discussed in section 4.4.

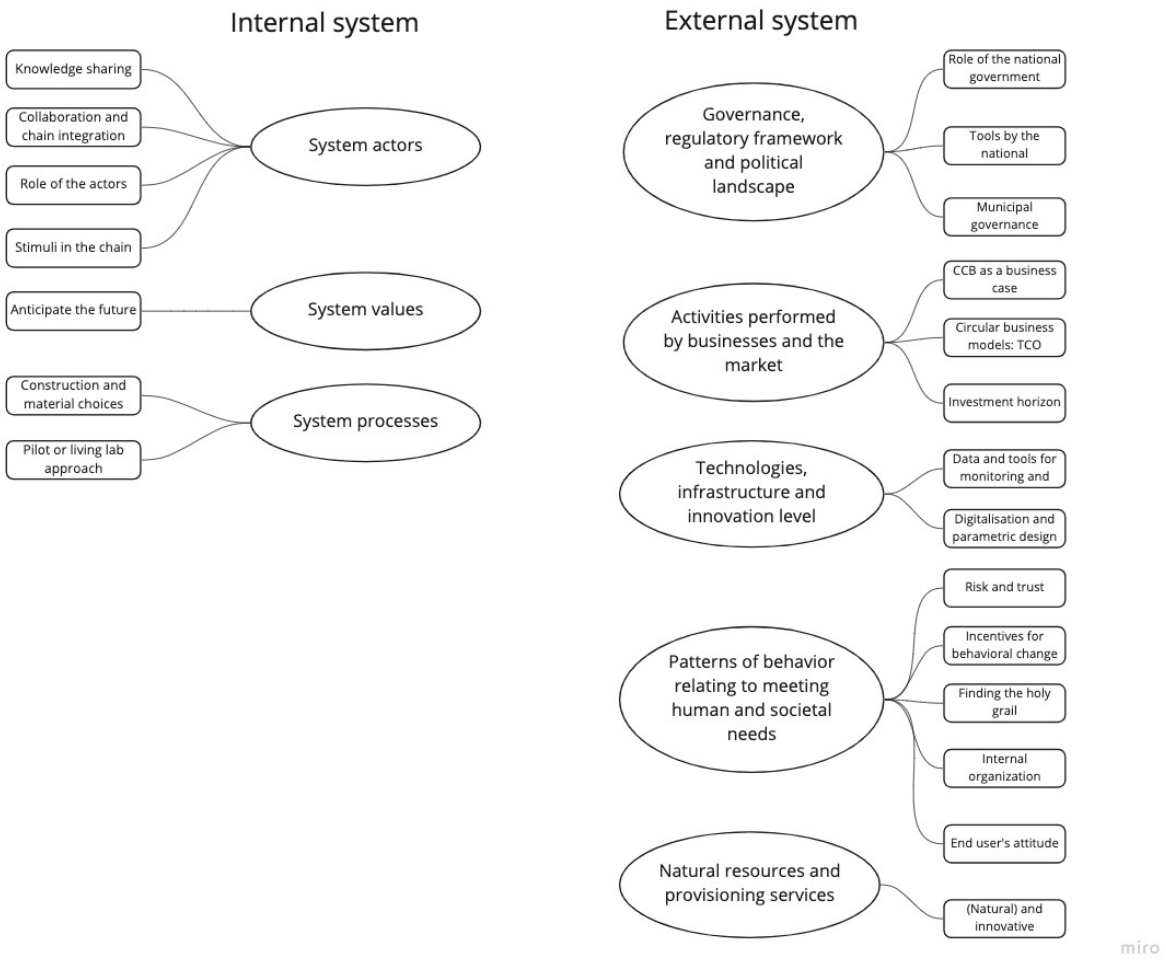


Figure 10 *Overview of themes per subsystem after interview analysis. Author's own work.*

8.2 Responses from the interviews

8.2.1 Definitions of CCB by respondents

The interview data implies that there is indeed not a clear definition of circular building and conceptual building that is adopted by all stakeholders. This section elaborates on the definitions and understanding of circular building and conceptual building by the respondents.

Circular building

It results from the responses that the notion of circular building is centered around various themes. One of the respondents argues, in line with this, "I think the strength, but also the pitfall of circular building is that it involves several themes. Partly materialization, but also adaptivity, toxicity of materials. There are a lot of components. I think it is also a strength, because we are working on a circular economy, which requires adjustments in various parts. But it also makes it vulnerable, because we are really in search of how to score, test and innovate in all these areas."

Some respondents mainly link circular building to challenges with raw materials and environmental impact. But other respondents think more broadly. One of them captures circular building in three notions, “On the one hand, reuse of materials by recovering them. Another component is that the materials you use are produced in the most sustainable way possible, looking at renewable crops and trees. Another component is that it can be reassembled in other places, so design for disassembly and reassembly.” He adds that there are a lot of raw materials that we know are better not to be used, like concrete and steel, but if it is already there, it is better to increase the lifespan of these materials. In line with this, a respondent agrees that biobased materials are part of circular building, but that it is not necessarily always better to use biobased materials, if you have a prefab concept in concrete and reuse and reassembly is ensured for the future.

The majority of the respondents stress the importance of looking at all phases of the building, in the context of circular building. One of them indicates, “It is really about material flows. They have to have a responsible origin, so biobased or reused for instance, but you also look at the future. How can they be reused again? An important condition for this is design for disassembly. That is a condition for making reuse possible in the future. And environmental impact is involved in that too.” Nonetheless, one of the respondents emphasizes the importance of becoming circular *now, “*Let us reuse concrete for construction and not push it under the road, and let us give the wood we already have a second life instead of turning it into biomass.” A concluding remark comes from one of the respondents, saying that you need to think well about circularity from various aspects, “sometimes you can use more material because it has less impact, not only on the environment but also on the total lifespan, because then it is sometimes easier to reuse it. Further, it could be justified in the form of insulation, so that the impact during the life phase of the building is smaller. There is also always a relationship between energy consumption and material use.”

Conceptual building

The majority of the respondents find it more difficult to define conceptual building than circular building. As one respondent put it, “Conceptual building is working from a concept, by way of more standardization and prefab. Therefore it works like lego. This is mainly beneficial because it reduces failure and construction costs. And therefore it has an advantage in material use and hence, less environmental impact.” Another respondent said, “it is the reuse of design and production elements. A standardized product with standardized elements.” Standardization is a term that resonates with many respondents in the context of conceptual building. Furthermore, many respondents link conceptual building to industrial building. One of the respondents emphasizes, “I believe that conceptual building is the basis for industrial

building, looking for unambiguous dimensions, materialization and detailing so that industrial construction can be carried out. I understand that you do not have to do conceptual building in a factory, but for me that is where it should lead." Another respondent adds, "Conceptual building is very easy to make, especially industrially. You can produce whole parts in the factory at high production speed, which could be used in different concepts. Because at the front, you have thought about the design. You design for disassembly or for flexibility in moving and reusing windows and door frames." The majority of the respondents agree that conceptual building leads to faster construction, and therefore better affordability. This is because of the shorter production time if you produce industrially, but also because the conceptual design is already thought out well upfront. This concept is reproducible, generally with modules or elements in 2D or 3D, so there is less design effort required per project to realize products. One of the respondents positively links conceptual building to circular building by arguing for conceptual building as a means to more circularity, by thinking of materials and opportunities for future reuse. Interestingly, one of the respondents is less positive about the term 'conceptual building'. He argues, "the word 'concept' contains some vagueness, as if it is not yet fully thought out yet. That gives uncertainty to the customer or client. So I never talk about conceptual building, because I want to get rid of that vagueness. It is super concrete! We can start tomorrow!"

8.2.2 Internal system

Actors

Knowledge sharing

Multiple respondents indicate that they find it important that the knowledge on CCB in the chain increases. The respondents believe that knowledge needs time to build up in the context of a new subject. Knowledge sharing increases transparency, which various stakeholders indicate as an enabling factor. Each actor in the chain has their own knowledge on the topic and sharing this leads to better understanding of the ambitions, requirements and opportunities. Without doing this, assumptions arise that are not always in line with the truth.

However, various barriers come to light. First of all, there is not a knowledge-sharing mindset amongst the chain. Respondents indicate that, even though this is changing due to shared ambitions, they still notice that there is the fear of making the competitors smarter by sharing knowledge. This competition is also noticed when actors engage in innovative projects in the context of CCB. There is a mentality where knowledge and outcomes are only shared when the project reaches the targets and thus is marked as 'successful'. Though, knowledge on the process of innovative projects

that failed or did not reach the targets is very valuable to learn from. Moreover, municipalities indicate that they do not have enough knowledge from market parties in order to develop the right local policies and requests on circular and conceptual building. They need experiences from market parties to adjust their policies, so that they rightly stimulate the market parties.

In order to increase knowledge sharing, respondents suggest knowledge sharing sessions between the chain actors as enabling factors. They indicate knowledge sharing as a first step towards collaboration and making arrangements. Municipalities are working on a structure in which they financially support the early stages of an innovative project, but ask for participation of the project leaders in knowledge sharing sessions in return. This leads to a higher level of knowledge and mutual understanding in the organizations. Moreover, respondents emphasize that knowledge should not only be shared amongst the chain partners, but also within the internal organization with those who are involved with the CCB. For instance the department of the municipality that issues the permits, or the building inspectors that have to test the circular or conceptual house.

Collaboration and chain integration

Generally all respondents agree with the statement that collaboration amongst the chain actors should increase. This is one of the most predominant topics in the interviews. Currently, each actor in the chain mainly protects its own costs and interests. Therefore, there is an attitude of negotiation rather than collaboration. This is indicated as a barrier. One of the barriers that the respondents currently experience is that each actor interprets CCB differently, resulting in different goals. “Currently, the chain actors do not speak the same language, and if they think they do, it will be different anyways in the end”, stresses one of the respondents. According to him, the actors should not impose a standard, but they should start by sitting together with their partners and expressing what is important for them as a client. Accordingly, the actors can have a conversation about these ambitions and how to realize them. Similarly to knowledge sharing, the actors learn from each other and how they could most efficiently engage in a project. “Actors need to join forces and determine direction together. They need to express what is possible and what is required from their side to make the project happen”, the respondent emphasizes. Housing corporations recognize this view as well. One of the corporations has created a document where they clearly state their definitions and ambitions, “We use this document in our communication with the municipality. If a civil servant is stacking and stacking demands in a project, we can actively counteract with statements from the document that are set from the beginning.” This is indicated as an enabler for clear communication as a starting point for efficient collaboration in CCB.

Further, City Deals and covenants around circular, conceptual or biobased construction are indicated as enablers for collaboration. Other respondents stress the importance of involving specifically municipalities, architects and contractors in early stages of a project for collaboration. “We should just start doing it. We can collaborate by making a team, following initiative from a corporation or developer for instance. Then we can look at the requirements of the tender together, set ambitions and do the whole project together”, a respondent suggests. This is supported by various actors who suggest the benefits of sharing risk and responsibility amongst chain actors as an enabler for the transition to a circular system based on CCB.

Moreover, one of the respondents argues for the importance of the developer, contractors and client to increase cooperation as an enabler to accelerate the production of CCB. He argues that they could even become one over the next few years. “Because with ‘the euro’ in one hand, and continuous volume from the client or developer, we could be more efficient and more affordable. Margin on margin will disappear. Now, everyone wants to knock out a 10% margin from this system, and the contractor often takes the most risk. But that is not going to last, there is not that much margin anymore”, he points out. This view on chain integration is echoed by another participant. He argues that chain integration or close cooperation is the only way to start thinking integrally, rather than passing problems on to the following chain actor. “More and more you see developers having shares in production factories, so I do believe that. From there they can influence the entire chain, and there is no other way to start thinking integral.”

Role of the actors in the housing construction chain

In the internal system, various actors in the chain are searching for their role and position in a circular housing construction chain. Asking the respondents about their role and the role of other actors in the chain, interesting perspectives arise.

Municipalities challenge and reward parties if they take an extra step on circularity with the tender process. The majority of the respondents acknowledges that the most important role for the municipality is to take control, set direction and provide unity in language and ambitions in the transition to CCB. However, municipalities are searching for their right role in the transition and the respondents express various barriers. Firstly, the municipality experiences that it is difficult to make suitable policy, since the market parties are diverse. Some parties do not know what to do with circularity and need guidance and incentive from the municipality, where other - more front running and innovative - market parties would like a different level of challenges and rewards. “We have very ambitious pioneers in the market, but there are a number

of laws and regulations in the way. And, of course, there are companies that are not really excited about the innovation that is coming. And they are slowly trying to resist. And that may sound negative, but from a business point of view I understand that. A lot has been invested in all kinds of conventional working methods and they now see that things are going in a different direction.", is argued by a respondent from a municipality. Respondents from various market parties argue that the municipality delivers building envelopes that are too specific and that the tenders pose too many solutions rather than goals or ambitions.

Also *area developers* are searching for their role in the transition to a circular system based on CCB. Developers aim for a financially feasible and sustainable plan with a revenue that is higher than the land and construction costs. As a central actor in the housing construction chain they develop based on the wishes from the client, end user and the local principles. However, in their traditional business model, there is no direct incentive to have a long term circular vision for their houses as they do not keep a stake in the houses over their lifespan. On the one hand, they aim to get incentivized for CCB by other chain actors and on the other hand they aim to be a role model that steers the chain towards circularity.

Besides traditional contractors and developers, new actors arise in the chain. These are *developers* that develop and industrially produce circular concepts. Asking one of the circular concept developers about their value proposition, he explains, "Our value proposition is that we are everything: designer, developer, contractor and investor. And from the start we all sit together. In the traditional process there are so many middlemen and margins. As a result we are much faster in the design process and the construction process, and we only have one margin over the total process that is probably lower than in the traditional process."

Another respondent believes that, while working from industrial concepts, the role of an *architect* will become more informing and engaging rather than designing, at least in the affordable housing segment. They could convince the municipality and the client to work differently. "If we want to build fast and affordable, we do not really need architects anymore for social and mid-market housing. We have the variants of the floor plans over the past 30 years, they are already invented. So you can also make them 3D in a factory. Then you can transfer all quality and labor to boost efficiency." Nonetheless, as discussed in the construction and materials section, aesthetic quality and local integration is crucial. Architects could monitor that. In line with this, one of the respondents argues, "We need such area development where people are impressed by the neighborhoods. I think developers have good insight in that. They should think about what kind of neighborhoods they are developing. I think there is also an

interesting role for architects, because industrial construction used to have a bad name because of its uniformity. I think this has quite an impact on the movement." Ideally, in CCB projects architects provide expertise on circular housing concepts and monitor local integration and aesthetic quality.

Stimuli in the chain

A considerable number of actors in the housing construction chain believe it is their responsibility to stimulate other actors to engage in CCB. Subsequently, multiple stimuli in the chain arise that are recognized as enablers to accelerate the transition to a circular system based on CCB:

• municipalities aim to encourage developers to include circularity in their project plans through tender criteria;

• developers could stimulate housing corporations, investors and end users with qualitative benefits with regard to quality of life and health, high sustainability performance and benefits during or after the exploitation period;

• developers could challenge contractors to participate in a circular project, for example with innovative biobased materials. They could award contracts to leaders on circularity in construction;

• contractors could challenge suppliers to provide service for their product over a longer timespan, incentivizing the supplier to deliver high-quality products with a long lifespan;

• corporations and investors could challenge developers to develop a circular project for their portfolio;

• residents and end users could encourage developers, corporations and investors to develop circular homes by expressing clear wishes.

System values

Anticipating the future

In order to anticipate the future, actors arrange their processes based on their expectations of the future. A variety of perspectives are expressed. First of all, contractors increasingly understand that resources are becoming scarce and expensive and that they should start investing in different materials to reduce environmental impact. This is an enabler to accelerate the transition to a circular system based on CCB. "That is also a financial incentive. I think that is required anyway. But one of

the largest brick factories suddenly starts investing in ceramic dust. That is because they see commodity prices skyrocket.", a respondent illustrates. This relates to impact in the economic domain. Likewise, investors and corporations indicate that they increasingly recognize the added value of circular and biobased projects in their portfolio, from an ESG (Environmental, Social, Governance) perspective and a future-proof perspective. One of the investors said, "We see that these are the buildings of the future and we will benefit from them in the long term in terms of value."

Furthermore, it is echoed by the majority of the respondents that it is crucial for government, clients and contractors to agree on doing things differently together. One of the respondents suggests, "if you agree on how you are working towards the future together from now on, then the client can start setting up their processes. Then the contractors and entrepreneurs will understand where the market is heading and that they should prepare." Hence, all parties should make clear statements about what they require to achieve future goals. In that way, uncertainty for clients and contractors is reduced and they are encouraged to invest in new production methods, materials and knowledge. Lastly, actors expect that buildings should respond more flexibly to changing housing needs in the future. One of the respondents argues, "we have to design for flexibility and disassembly, instead of building concrete houses that have to remain intact for 60 years for the business case, but will not meet the desires of the users in the end." This is a common view amongst the respondents. Hence, it is important to think well about the functional and economic lifespan of housing.

System processes

Construction and material choices

One of the barriers in the transition to a circular system based on CCB is little experience with biobased materials. Respondents indicate that various contractors or suppliers are risk averse towards working with biobased materials, as they experience a knowledge gap in comparison with their traditional way of working. A respondent argues, elaborating on material choices, that contractors and developers should think well about various materials and demountable construction methods. Respondents from the developers argue that they put large effort in R&D to develop a concept that is as circular as possible. One of the barriers that respondents experience is the wide range of aspects to consider for CCB.

One of them firmly believes that we should not start constructing everything in new timber. "Because if we approach circularity like that, we will only actually be circular in 60 years from now". Therefore, they have decided to work with concrete that is reused so that they can make a waste product into a new product for the next 50-70

years. Other concept developers decide to develop a fully biobased construction in an open system with beams and columns. This allows for a large variety of floor plans. For them, a circular concept should focus on biobased materials. Furthermore, changing demographics and the reuse of modules benefit from concepts that are designed for disassembly. For that, developers work with 2D or 3D modular elements. 2D elements allow for more flexibility which is useful in complex construction sites, whereas 3D elements could be more time and price efficient. However, many respondents highlight the importance of spatial quality and local integration of a housing project. Standardization with industrially produced modular elements could jeopardize that. A respondent that develops industrial concept buildings adds to this, "I think that finding the balance between standardization and repetition and being able to develop unique buildings with maximum commercial and architectural quality is our main challenge for upscaling."

Coming back to the wide range of aspects to circularity, one of the respondents explains their method for measuring circularity, "The method is certainly not perfect, but it is helpful in steering the design process. We look at the source of materials, the future scenario, disassembly and environmental impact. If a product has a low environmental impact, but scores poorly on disassembly, then we see where they need to steer and improve. The outcome tells us something about the integral product."

Pilot or living lab approach

Recently, several pilot or living lab projects have been started with circular and conceptual construction. The opinions on this are divided. Many respondents are done with pilots and prefer to focus on scaling up circular and conceptual building. Nonetheless, pilots and living lab projects are valuable if conducted properly. Currently, pilots are often a goal rather than a means. One of the respondents argues, "When you do a pilot, it has to be with a purpose. You have to decide in advance how you are going to approach the rules of the game in the organizations, so that you actually learn from the project compared to previous projects. What do we need for this, and who do we need, besides the sustainability manager." An essential purpose of a pilot or living lab is the opportunity to use the results for further projects, so that they have a function in upscaling CCB to other projects. This is echoed by the majority of the respondents.

Another recurrent theme in the interviews was a sense amongst the respondents that pilots are often poorly evaluated, which is a barrier to upscaling. One of the respondents argues, "When doing a pilot project, you have to determine in advance what you want to measure in the end and what you are going to criticize. Because otherwise you will look back in the end and think: we did not measure that, or we did

not include that at all. When you determine in advance what you will monitor and who is responsible for that, you can have an effective evaluation at the end." Therefore, it is important that actors and financiers remain involved during the process. A respondent stresses, "You notice that if a pilot lasts a number of years, and the alderman or another important person concerned is not in function anymore then the pilot is financially closed, but no one is actually involved in the results and evaluation." The points of evaluation should be shared with other actors, to learn from the projects. One of the respondents stresses that it is crucial to share failed experiments and learn from them. He argues that failed outcomes should be framed differently, "If you did not do anything wrong, then you have not been innovative enough. So if nothing goes wrong, your pilot has failed."

Moreover, pilots or living labs could serve as an enabler in the context of the local or national governments. In a pilot or living lab project, a goal could be to prove that something is possible if things are done differently. This is a good starting point for a conversation with the government on what is required and how that could be translated to policy. Similarly, this requires effective monitoring and evaluation.

If pilots or living labs are conducted and evaluated properly, they could be valuable. Respondents argue that pilots have the potential to 1) bridge the gap between scientific innovation and society, 2) be a 'safe space' where certain rules do not count and failure is seen as less problematic and 3) to showcase the enthusiasm of innovative frontrunners.

8.2.3 External landscape

Governance, regulatory framework and political landscape

Role of the national government

In all interviews, the respondents expressed an opinion about the role of the national government. The majority indicated that they would benefit from tighter control, more coordination and specific direction from the national government. "I believe more in a strong government that takes lead and less leaves it to everyone. That is what is happening a lot with the Dutch polder model." a respondent states. Elaborating on what market actors need from the government, a respondent stresses that clear, long-term policies are crucial for entrepreneurship and investment, "Now the market is more aware of what needs to be done, so they will just start doing that. But if you have a government that is still in doubt, the market will be afraid that they are barking up the wrong tree. They might choose to go right, and the government will go left in the end." Another respondent adds, "I learned that the national government is always trailing behind, because all parties should be able to meet their legislation. So they cannot go too fast. But what they can do is develop a clear framework of where we

want to be in 5 and 10 years. They could do that more." This view is echoed by the majority of the respondents. They confirm that there are future visions, for instance the Paris agreement and the Dutch climate agreement. Nonetheless, a clear roadmap with accurate legislation, perspective on the medium-term and concrete goals is lacking. Respondents were unanimous in the view that this is a barrier to the transition to a circular system based on CCB.

In order to develop and implement suitable legislation, respondents from a governmental organization stress that they need reporting from and communication with market parties. One of the respondents argues, "It is a chain reaction. The market parties need us, but we also need input from the market. We want to understand what is going on with a corporation, developer and builder." Therefore, another respondent elaborates on the importance of proof, "That is why I think that quantification should continue, because that is how it goes with policy; it must be scientifically substantiated, and then the train starts moving." But it is also about the right communication. Respondents argue that City Deals have the potential to facilitate connection between the government and the market. Nonetheless, one of the respondents explains that it is complex to find an efficient way of working together, "That connection with the government is certainly nice, because it allows us to immediately report to the Ministry what does not work and what should be improved, with a substantiation. But I have to get used to working together with the government. I prefer to just start doing things, create an example and thereby burden of proof that policy must be changed. But the government is much more about talking and inspiring. But we just have to accelerate. We have already inspired a lot."

Tools by the national government

The majority of the respondents feels that the national government does not have a wide variety of tools available to steer market parties towards their ambitions. The most recurrent topic in the interviews related to these tools, is the Environmental Performance of Buildings (MPG), which has to be calculated for the application of an environmental permit for new build houses. The MPG can be calculated, and indicates the environmental impact of materials used in a building. Respondents from municipalities agree that the MPG is a helpful tool to verify a sustainable building. "Certainly in a tender, it must be verifiable. Because how do you determine when a building is sustainable? Then you can use BREEAM, GPR or MPG. You can express your ambitions with those tools, and it is easy for us to test if the requirements are met. Otherwise you get a lot of subjective solutions. That is sometimes difficult for us at the municipality." Per July 2021, the MPG has been tightened to 0,8 by the national government and the goal is to tighten further towards 2030. Many respondents agree that the MPG needs to be tightened further, as an enabler for the acceleration of the

transition to CCB. “Then the transition will certainly start. Even traditional buildings could reach an MPG of 0,8. If we lower the bar, many traditional buildings will not pass.” Nonetheless, in all cases respondents indicated that they want to be informed in time of a tightening of the MPG, which relates to the government having a clear roadmap on legislation as discussed in the last section. “We want to be ahead of the legislation, if the MPG is tightened to 0.5. Then we should already be doing something about it.” Another recurrent topic is that the current MPG is not suitable in the context of CCB, and that different factors should weigh in the calculation. “What I hear is that the weighting of biobased materials is still limited. If that weighting is included, and the MPG requirement is tightened, then you get that incentive at the front and in construction. Then it really pays off to start building biobased.”, one of the respondents argues.

Besides the MPG, a variety of respondents argue that they would indicate subsidies and fiscal arrangements as an enabler to accelerate the transition, especially in the early phase of the transition. This could be a subsidy scheme or a tax scheme, “ Or if you obtain an excellent BREEAM label, and thus have a sustainably certified building, you will receive tax benefits. They could do certain constructions.” Nonetheless, this is not identified as a heavyweight topic in the interviews. An existing fiscal arrangement is the MIA\Vamil, an investment deduction. A respondent explains that the Ministry has financial resources for financial arrangements to boost housing construction, “There we try to add as many circular, climate adaptive and nature inclusive aspects to the arrangements so that market parties start building in the right way, also in Delft and Groningen.” Another respondent replies that this process is likely to be similar to the energy transition: ‘First, subsidies were needed for solar panels and sustainable development. If you do not give that subsidy, nobody is going to start. After a while, when more people start doing it, the subsidy can be removed and the price settles.’

Municipal governance

Turning now to the local political landscape, respondents were asked what they demand and need from the municipality to accelerate the transition to a circular system based on CCB. The majority of the respondents identified the current municipal processes in area development as a barrier to the acceleration of the transition. The market actors mainly stress that the permit processes and issuance processes should be faster. Another respondent argues that if we want to seriously tackle the housing problem in the short term, municipalities need to be more flexible with the land on which houses are constructed. He argues that the key lies with the municipalities, but that the municipalities will have to be given tools from the national government for this flexibility. There is a reciprocal relationship between the

municipality and the national government. Asking specifically what he demands for, he says, “Just more stamps that say ‘approved’. Often when we get granted a permit, it contains so many reservations that I think: is this a permit? or a letter of advice? They just have to say: the plan you submitted has been approved. Done. Now they make it so complex for themselves and for the party they are doing business with.” Further, he adds, “If something deviates from the Building Decree, they should use common sense and think well about it. If people can live in it just fine, then they should approve it. Then you get plans through more easily.”

Especially developers indicate that they need more flexibility and an innovative view on conceptual, industrial construction. “They can subsidize endlessly further in the chain, but ultimately all creativity is determined at the moment of issuing the land. Municipalities prefer everything to be modular and industrially built, but it comes with an accumulation of requirements. We are tied to fixed sizes and fixed heights, so that clashes.”, says a respondent. Another respondent that develops circular concepts adds: “our design and construction process is much faster. But we are always dependent on the municipality and their capacity. So the planning processes are currently the most decisive factor in the spatial environment to achieve this acceleration.” A respondent from the municipality acknowledges, “It is not that we do not want to be more flexible with industrial concepts. It is simply that the municipality has been optimized on traditional buildings, so that this brings an extra compensating factor if you get sizing and dimensions in it. I think we have to look at each location that we designate how it fits with the zoning plan and if that becomes a nuisance.” In general, respondents from the municipalities understand that the duration of their planning and permitting process is a barrier, and a challenge in the transition to a circular system based on CCB. However, their internal organizations have many departments involved in area development, and it is challenging to mobilize all departments to move from the traditional way of working to a more flexible and faster approach.

Activities performed by business and the market

CCB as a business case

A strong circular business case is identified by the respondents as an enabler for the acceleration of the transition to CCB. The majority of the respondents indicate that CCB comes with higher investment costs. But due to economies of scale with conceptual industrial building costs per house decrease, making industrial CCB an attractive solution for housing construction. Another respondent adds, “When the house is prepared in a factory and then put down on the construction site in a short time, that is advantageous for us because it reduces costs in our investment story. With a short production time we can receive income from rental faster.”, indicates an

investor. Another financial benefit highlighted by the conceptual developers, is that the accumulation of margins disappears with industrial conceptual developers. Many respondents stress that these financial advantages should be showcased more.

Another respondent argues that it is also about other returns, besides financial. He argues that a customer needs to accept a slightly lower return, but having a better building in return. Nonetheless, concerns are expressed about that view. One of the conceptual developers stresses, “It irritates me immensely that people often think that a circular home could cost 10 or 20% more. Then the business case very often does not hold, and you will never have a largely scalable product.” The majority of the respondents agrees with this, arguing that the business case is a crucial enabler. One of the respondents elaborates, “Ultimately, what matters to us is the return. The social return is important, but the financial return is essential. As soon as the costs for circular construction really decrease and meet the costs of traditional construction, it is a no-brainer to start building circularly.” In line with that, the conceptual developer explains that they have decided to similarly adhere to the costs per gross floor area as traditional contractors. “We want to be in line with the market prices. If the costs are similar, clients can easily compare. Do they want a future-proof house, or an old-fashioned home from a traditional builder X Y or Z?”, he states. Furthermore, he stresses the importance of complying to market prices by explaining that housing corporations and investors in social or mid-market rent cannot exceed certain construction costs because they are dealing with a rent ceiling, “Corporations and investors have a great challenge meeting the increasing construction costs and land costs to realize affordable housing. I think that is where the pain is in the market right now.”

In all cases, the respondents agree that it is essential to invest from the start of the project, by reserving a budget for circularity. One of the respondents especially has a clear opinion about this, “How we are working now is that afterwards we understand that we have a problem with the linear economy and we put billions to fix these problems. We call that symptom management. But what if we use those billions at the start of the process. If you put 10% extra on your project, but make sure that you reach all circular goals and ambitions then we do not have to clean the mess at the end. Then you find out that this *unprofitable top* does not exist at all, if you determine at the beginning what needs to be done differently and what the ambitions are, instead of at the end.”

Circular business models: total cost of ownership

One of the barriers to accelerate the transition to a circular system based on CCB, is that circularity is generally not rooted in business models. “It is getting more attention,

and people are starting to understand it better, but this concerns the entire industry, also banks and appraisers.", one of the respondents argues. "We are used to looking at investment costs in the business model, but especially with circular projects you have to look at your total cost of ownership (TCO)." Nonetheless, the majority of the respondents indicate that they do not work with the idea of TCO yet. "Rather, we calculate with an increase in value over time, so that we can sell to another investor or resident eventually. Financially, TCO or residual value has a nil role in that regard I think." A respondent argues, "We are all really good at backcasting, so determining what something will yield in the future based on experience. But forecasting, to really look ahead, that does not work yet." Nonetheless, various respondents identify the opportunities with TCO as an enabler for investments in CCB. "Corporations and investors have a housing fund, but they also have a material or commodity fund. They do not realize that enough. I am convinced that in 5 or 10 years there will be speculation on the components of houses. The raw material balance that they have in their portfolio is very valuable. But that is something they do not yet dare to take into account.", one of the respondents states.

Conceptual developers seem most innovative in including residual value or take-back guarantees in their business models. One of them explains. "We now dare to say that we will give back 25% of the construction costs, as a sort of deposit if we take the houses back after a maximum of 15 years." Besides, they are challenging their suppliers to be responsible for the maintenance of their items. "We have always asked our suppliers: do you dare to do the maintenance yourself for the next 30 years? If the answer is no, then they do not dare because they deliver a low-quality product." Another respondent is working on developing calculation methods for residual value for conceptual developers in different scenarios, "For over 15 years, and over 30 years. But most important is, how can we give that guarantee? Someone has to guarantee it. We could give the customers a discount upfront as an investment damper, or to ensure that they get money back when the materials return. So we are talking to banks, or seeing if we can set up a seperate BV to put that guarantee there. But that wheel has not been invented yet. And it is also about how actors like corporations positively include this in their accounting, so they do not calculate back to zero."

Investment horizon

Certain actors in the chain express that they experience the long horizon of circular processes as a barrier, especially if the concept of residual value will be further embedded in the business model. This is something that especially project developers indicate. Another respondent also highlights this, "For project developers, working towards a TCO idea is difficult, because they do not get that value back. Therefore I think housing corporations are ideal to look into." Housing corporations and investors

work with a long investment horizon in any case. Therefore, they are present in the entire lifespan of a house. Investors indicate that they are attracted to investing in biobased buildings to prevent stranded assets, “From an environmental point of view, we buy a better building with a timber building rather than a fossil building. That is what we mean by stranded assets, that the fossil building will represent less value in the future.”

Technologies, infrastructure and innovation level

Data and tools for communication, monitoring and evaluation

In order to effectively monitor CCB projects for evaluation it is important to collect and analyze data. One of the respondents from a housing corporation highlighted how they made a number of their projects insightful with data. He commented, “We did it to know how to improve the circularity related to the multi-year maintenance, and it is very helpful to report a quantitative number in our technical policy and our documents to contractors.” However, one of the barriers that the majority of the respondents experience, is that it is still remarkably difficult to -quantitatively- express the level of circularity. Another housing corporation makes an appeal to parties that focus on R&D or innovation to make circularity more quantitatively insightful and to create standards. It is efficient if the actors simultaneously decide which tools and standards are adopted so that the focus will be on these. The government could take control in guiding that process. Respondents agree that eventually, there should be one adopted method; one that actors could steer with.

Many attempts to quantify sustainability or circularity are concerned with CO2 emissions. A respondent also argues that making circularity quantifiable is very important. She highlights CO2 equivalents, where other greenhouse gasses are converted to CO2 and she says that with buildings, actors often refer to the MPG or MKI but that they are also working on translating that into CO2, so that numbers could be compared and added together. Nonetheless, a large share of the respondents articulate that quantifying CO2 is less complicated than expressing the value of social or other environmental benefits. Another respondent says, “And yes, we can measure what a timber building does in terms of CO2 storage. It is good that we are taking those steps, but we should also look at how much water a building captures and how much biodiversity it adds.”

Digitalisation and parametric design

One of the possibilities related to industrial conceptual building is the opportunity to make a parametric model. In a parametric model, features are shaped according to algorithmic processes, instead of being designed directly. Parameters and rules determine the relationship between design intent and response. It is generally

experienced as an enabler, as it provides freedom to experiment with variety using computer models. Nonetheless, one of the conceptual developers interestingly stressed, “With parametric designing, there has to be a very clear difference between the means and the end. Sometimes you can already quickly see where a project is going, and you do not need that extra brain power at all. A parametric model requires a lot of data and information, so that the model can be smart. But if there are only a few options, then there is no point in filling such an entire model.” He adds that it could be a very useful tool to obtain the optimal result for locations that are very complex. “And then a modular system is perfect, because you already have that information. You already know how your system information is put together, you just have to put it in and the model can start calculating.”

Patterns of behavior relating to meeting human and societal needs

Risk and trust

Issues related to risk and trust are a recurrent theme in the interview data, mainly concerning the organizational level. A variety of respondents acknowledged that they experience a risk averse attitude with various actors that are involved in housing production, which is a barrier to the transition to a circular system based on CCB. One of the respondents stresses that she associates this with patterns of behavior and the social context, “Change is scary and preferably you want to continue doing what you have been doing. So that is much more on the social and behavioral side.” Another respondent echoes this view by stating, “I believe you can take a lot of measures without it costing extra money. But there is also a bit of conservatism, and a bit of fear in people. They have been doing projects in a certain way for 20 years and it works well. Now something changes, and a risk emerges that they run out of time or it does not meet the budget.” One of the respondents indicate cooperation with experienced organizations as an enabler to accelerate the transition to CCB. Nonetheless, there are still very few organizations with a track record on CCB.

Incentives of behavioral change

Several incentives for behavioral change have been mentioned by the respondents, as enablers to accelerate the transition to a circular system based on CCB. One of the respondents started with the importance of framing, “It is not about ‘willing’, it is about ‘having to’. The only question left then is *how.”* This view is widely supported in the interviews, mainly by sustainability managers. However, the question of how to mobilize actors is complex.

Various respondents indicate their social policies to be an incentive to change. These often include environmental ambitions. Especially institutional investors highlight their position in which banks, pension funds and insurance companies are often the

major investors behind institutional real estate investors. “They do not determine the policy, but what they think is very important for what the real estate investors do.”, one of the respondents explains. Another respondent adds, “Pension funds in particular find it very important to do something good for society with the pension money. Pension funds also get questions from their participants about what is done with their money, so that is very important to take into account.” Institutional investors can showcase their sustainability results with GRESB (Global Real Estate Sustainability Benchmark). “GRESB is very important to us. They annually investigate what is done. With sustainability, it is our most important benchmark, as it compares our organization against our peers and there is a ranking.”, one of the respondents from an institutional investor states.

In spite of societal incentives, one of the respondents states, “I know that people only actually mobilize for two reasons: when they are punished, or when they are given money. That plays a role.” These two factors came up with various respondents, in the context of crisis and financial incentives. One of the respondents remarks, “we have two natural developments that point very much in the direction of circularity, labor potential and the material prices and availability. Circular industrial construction could be an answer to both. But it seems as if that is not really getting through with actors. I find that quite surprising, but that really is the linear system we are in. It is very hard to adapt.” This leads to the question with the respondents how devastating a crisis should be, before it would change mindset and processes in the long term. “Maybe we need a serious disaster in Amsterdam or Rotterdam, an earthquake or flood. With Covid-19, we experienced that a lot of things can suddenly be fixed within ‘emergency laws’. Then we can all of a sudden spend 80 billion to not let actors go bankrupt.” One of the respondents remarkably argues that revolution never arises through innovation, but rather through crisis. Then actors will start looking at innovations. Tools and innovation instruments are helpful incentives to bridge the gap from behavioral change to implementation of different processes, “At the start, this could also be financial instruments, so that there is an extra reward. It could help actors to find partners who dare to go along even if there is no 100% certainty.”

Finding the ‘holy grail’

From the framing of several respondents on CCB, a focus on biobased or timber construction arises. A barrier for a successful transition to CCB is that actors wish to find ‘the holy grail’, according to one of the respondents. He argues, “We are going to make mistakes, we are going to make things sacred. If actors want to go fast in a transition, they like to find one solution for all.” However, several respondents emphasize the importance of customization per project and area.

Internal organization

Various respondents stress that the largest barriers for the transition to a circular system based on CCB are concerned with the culture of the internal organization. “If you want something different, but everyone around you does not, then you are crazy. That is how it works at the organization too. Some people like to take that role, but they encounter a lot of resistance. It is really a social thing.”, one of the respondents illustrates. Another respondent identifies as someone who likes to take that role within a housing corporation, “I am a leader in that. If you ask 100 people, there are always 20 or 10 who are negative. But if you know that what you are doing is the future, should you then listen to those people? I think not. You just have to do it and then the organization will adapt.” Furthermore, he emphasizes the positive stimulation he experiences from his manager, which gives him the energy to involve and inform people constantly. Another respondent elaborates on this by stressing the importance of directors and managers in the process, as an employee is always accounted for by his team and manager. Asking the respondent what he would do if his manager was not as supportive, he responds, “I would show him the advantages of CCB and make him see the quality of those houses. That technically it is 100% under control. And I would make him aware of the disadvantages of traditional building: CO2 emissions, time, burden on the neighborhood, material problems and inflexibility.”

Moreover, this theme also concerns a change of internal processes, for instance with housing corporations. This is illustrated by one of the respondents, “We have employees driving around with maintenance tools for our houses. They have a fixed arsenal of stuff. It turns out now that you need different things with biobased constructions. So from the moment you are going to build biobased, you have to include them in the process of change. Because if you continue to fix it with the same stuff they have in their van, you exclude a lot of possibilities.”

Besides, the role of sustainability managers in organizations is discussed. Opinions differ on what role the sustainability manager should play in the internal organization. Several respondents emphasize the importance of focusing on mobilizing other people in the organization, because the sustainability managers are already willing. They cannot guide the transition on their own, and it should not remain with the sustainability manager. Other respondents stress the important role that sustainability managers have in building a network and exploring within their organization who is important to involve, “Sustainability advisors know best who is required or enthusiastic within the company. You could have a conversation with the sustainability manager first, and they can direct you to the right persons to involve.”

End user's attitude

End users of the houses could give an incentive to the housing construction chain to transition to CCB. A respondent from an institutional investor argues, "if the resident gives more appreciation to circular buildings, that would help a lot in the whole transition." Hence, a positive attitude of the end users is an enabler to accelerate the transition to a circular system based on CCB. However, according to several respondents, this does not come naturally. A respondent from a housing corporation argues, "The average tenant does not really care about a biobased house with straw insulation. People just want a house, whether it is concrete or timber. So you have to take those people in the process." Therefore, it is important to give end users a positive experience with a circular or conceptual house, and make them aware of the environmental advantages. This is an opportunity for corporations and developers, "we do not really do that yet. But we should include that in our organization. To make the residents ambassadors of the circular house and its principles." Another respondent indicates that more end users will demand for CCB if they understand and experience the advantages. This is similar to solar panels and a lower energy bill, he stresses. On the other hand, there are examples where end users take the lead in demanding for CCB, which is indicated as an enabler. This is illustrated by one of the respondents, "At a participation meeting, an end user asked: nice all the green, but how will you deal with circularity? That was nice to hear. Apparently some people know a lot more than we sometimes think. I believe that support from society weighs very strongly in whether things are applied or not, besides the financial aspects."

Natural resources and provisioning services

Natural and innovative resources

(Natural) resources are at the basis of the internal system processes. As explained before, increasing prices of traditional resources are an enabler to accelerate the transition to a circular system based on CCB. It stimulates stakeholders to explore circular or biobased alternatives. For instance, in the context of natural resources, it is important that contractors, architects and developers cooperate with biologists and agriculturists to invest in R&D. They could create valuable ecosystems to cultivate biobased construction materials like hemp, reed and cattail. Furthermore, bacteria, algae and fungi offer interesting potential for isolation, coating, tiles or flooring. In order to facilitate space and an attractive investment landscape with the right policies and subsidies, it is essential that the Ministry of Agriculture, Nature and Food Quality is aware of the opportunities of cultivation for the construction industry. However, using the aforementioned materials in housing is still in its infancy and is not a recurrent theme in the interviews. The interview respondents mainly discussed the use of timber in the context of biobased or natural resources or reusing resources like concrete or specific elements.

Table 4 *Barriers and enablers per subsystem from the interviews. Author's own work.*

Internal

System actors

Barriers	*Enablers*
* Each actor approaches circularity differently; different goals * Each actors protects its own costs and interests * Bias and assumptions about actors in the chain *Negotiation rather than collaboration in the chain	* Chain collaboration for sharing risk and responsibility * Each actor having a clear role and responsibility in projects * Developer, client and contractor increase cooperation * Increase of knowledge sharing *City Deals and convenants for knowledge sharing, inspiration and action * Clear document with definitions and ambitions for communication * Clear communication about change in the future to reduce risk for clients and contractors * Stimuli in the chain

System values

Barriers	*Enablers*
	* Recognition of value of circular and biobased projects from an ESG perspective * Understanding that traditional resources are becoming scarce and expensive

System processes

Barriers	*Enablers*
* Processes are designed for traditional construction methods * Risk averse for change of processes due to little experience with biobased materials *Wide range of aspects to consider for CCB * Time costly R&D process to develop a circular concept * Local integration and aesthetic quality of industrially produced houses * Pilots/living labs as a goal rather than a means * Outcomes from pilots/living labs are not translated to policy	* Design for disassembly * Modular 2D elements for flexibility in complex locations * Modular 3D elements for time and price efficiency *Pilots/living labs to bridge innovation and society * Pilots/living labs with clear ambitions, KPIs and evaluation * Reporting results from pilots/living labs to government for policy

External

(Natural) resources and provisioning services

Barriers	*Enablers*
* Little knowledge on biobased and innovative materials * Large focus on timber rather than other biobased materials	* Cooperation with biologists and agriculturists * Cooperation with ministry of Agriculture, Nature and Food Quality

Technology, infrastructure and innovation level

Barriers	*Enablers*
* Difficulty to quantify and express level of circularity * Too many tools and instruments	* Adoption of one language with methods and tools for communication, monitoring and evaluation * Quantification with CO2 equivalents * Parametric design for industrial building in complex locations

Governance, regulatory framework and political landscape

Barriers	*Enablers*
* Vague long term ambitions and goals by the national government * Lack of capacity in the regulatory framework * Accumulation of requirements of municipalities * Dependence on slow governmental and permitting processes * MPG lacks in weighing circularity factors * A rigid relationship between the government and the market after tender processes	* Clear roadmap by the national government with accurate legislation, perspective on the medium term and concrete goals * Communication and reporting from market parties to government * Subsidies and fiscal arrangements * Flexibility in regulatory framework for innovative building concepts * Tightening the MPG and communicating this beforehand

Activities performed by business and the market

Barriers	*Enablers*
* Costs * Circularity not rooted in business models * Actors are experienced with backcasting but not with forecasting * Long investment horizon * Guaranteeing residual value * Including residual value in accounting	* Strong business case for CCB with similar financial returns as traditional housing * Shorter production time with industrial building for faster returns from rent * Economies of scale * Invest in circular goals from the start of the project - add 10% * Preventing stranded assets * Including residual value and take-back guarantees in the business model * A business model based on TCO * Raw material balance in portfolio of corporations and investors: future speculation on components of houses

Patterns of behavior relating to meeting human and societal neeeds

Barriers	*Enablers*
* Risk averse attitude * Difficulty of changing behavior in the long term * Conservative mindset * Wish to find the ' holy grail' * Conservatism in internal organization * Average tenant does not care about a biobased house	* A crisis for behavioral change and adoption of innovation *Communicating the benefits of circularity *GRESB for investors *Incentivization and pressure from other stakeholders * Management in internal organization shows leadership on circularity * Sustainability manager motivates and find the right people in the internal organization * Make the end user ambassador of circular house

8.3 Analysis of barriers and enablers per subsystem

The thematic analysis results in various themes. Accordingly, barriers and enablers are identified within each theme that are discussed more extensively in section 8.2. Table 3 shows the framework barriers and enablers per subsystem. This allows for comparison and synthesis with the results from the literature review and focus group. Furthermore, this section analyzes relevant insights of the overview of barriers and enablers per subsystem.

The interviews resulted in a large number of barriers and enablers in both the internal system and the external landscape. The respondents agree with the outcome of the focus group that the transition to a circular system based on CCB in housing construction is mainly an organizational challenge with the *system actors* in the internal system. Similarly to the outcomes of the focus group, collaboration in the chain, knowledge sharing and a clear role with responsibilities for each actor in the chain are identified as crucial enablers.

In terms of *system processes,* it is interesting to mention that many respondents indicate the current approach of pilots and living-labs as a barrier rather than an enabler, as they serve as a goal rather than a means. Besides, an important barrier that is identified is the wide range of aspects to take into account related to CCB. This demands an integral approach. Developing concepts with modular 2D or 3D elements are identified as an enabler to support the idea of disassembly and flexibility, which has been discussed in the focus groups as well.

Interestingly, similar to the focus group there are no barriers and little enablers identified in the *system values* subsystem. A possible explanation for this could be found in the definition of ‘values’ in this context; the positive and negative impact in the four domains (environment, economic, social and technical) as a **result of** actors and processes. Therefore, it is plausible that the barriers are rather related to the process and actors subsystems since the outcomes from these systems determine the impact in the domains. Aiming for positive impact in these domains, however, is repeatedly mentioned as an enabler relating to system values.

Moreover, there are multiple barriers and enablers identified in the *governance, regulatory framework and political landscape* external subsystem, concerning local as well as national governance. The most important barrier in this context, is the vague, long-term goals by the national government. A clear roadmap with perspective on the medium term would be an enabler to overcome this barrier. Similar to the outcomes of the focus group, there are various barriers and enablers in the external subsystems *activities performed by business and the market* and *patterns of behavior relating to*

meeting human and societal needs. These mainly validate the importance of circular business models, a clear business case and behavioral change, stressing the need to move away from a conservative mindset.

Furthermore, similar to the literature review and the focus group, little attention is paid to the barriers and enablers related to the *natural resources and provisioning services* subsystem. In contrast to the focus group, the interview respondents elaborated more on innovation, digitalisation and relevant tools to quantify circularity and to communicate, monitor and evaluate circular processes. These are identified as enablers related to the external subsystem *technologies, infrastructure and innovation level*. This is in line with the expectation in section 7.4 of more barriers and enablers in this subsystem when stakeholders from the external landscape are included as respondents. Furthermore, a respondent from a housing corporation explained how they demanded innovative parties to make circularity more quantitatively insightful. Still, there are relatively little barriers and enablers in this subsystem. Another possible explanation for this might be that in this phase of the transition, there is little demand for technologies and innovations in the field. Possibly, the regulatory framework and the market should have a clear direction and a roadmap towards circularity and subsequently, the demand for more supporting technologies, innovations and tools will follow.

8.4 Conclusion

The main aim of the interviews was to validate and further explore the barriers and enablers that have been identified in the literature review and the focus group. The interviews have resulted in a considerable amount of valuable empirical data from actors in the housing construction chain and stakeholders that impact CCB in housing construction. The outcomes from the literature review and the focus group served as input for the interviews, but the variety of topics discussed was broadened due to interesting views and insights from the respondents. This is noticed from the increase in themes in the thematic analysis of the interview data. The following subquestion was posed: *How are barriers and enablers to accelerate the transition to a circular system currently experienced by actors in the internal socio-technical system and stakeholders in the external landscape?*

Due to the diversity of participants, the interviews have brought about an integral view of the barriers and enablers that are experienced to accelerate the transition to a circular system based on CCB. The results from the interviews predominantly corresponded with the results from the focus group, focusing on process and organizational aspects rather than technical aspects to accelerate the transition. It is worth mentioning that the importance of chain collaboration in the housing

construction chain is hereby often emphasized as enabler. It is helpful to share risks, responsibility and knowledge and to define clear goals, ambitions and KPIs together from the start of a project. Many respondents argue that in line for this to happen, behavioral change on different levels is required: behavior of people to understand the need for change, behavior and attitude of the internal organization and behavior related to trust between actors in the chain.

Nonetheless, even if actors collaborate from the start of a project, it is still essential to have a strong business case for CCB to have a financially successful project. The importance of financial prosperity is oftentimes highlighted throughout the interviews, this time complemented with valuable insights on possibilities for a business case and quantifying and measuring circularity. Lastly, actors and stakeholders that want to engage in CCB indicate to benefit from a roadmap towards the broader climate goals by the government. This roadmap should consist of accurate legislation and involve goals on the medium-term. This helps actors to mitigate risk and adapt early to legislation.

9. Synthesis and tool to support actors in the transition to a circular system

This chapter is set out to synthesize the results from chapter 6, 7 and 8 in order to develop recommendations for interventions in the system to help the actors in the housing construction chain accelerate the transition to CCB. This is in line with the final sub research question: *Based on the synthesis outcomes, which interventions support actors in the socio-technical system, and where in the system could these be implemented?*

The goal of the synthesis is to find prevailing barriers and enablers in the various sources of data as well as their location in the system, in order to develop these interventions and propose a practical tool to support the actors in the housing construction chain. The synthesis follows a pattern-matching approach, that is based on finding overlap in the themes. The clustered summary of results per chapter allows for evident exploration per subsystem. Nonetheless, throughout the empirical research, certain barriers or enablers were often emphasized or indicated as important in present-day acceleration. These are discussed in each chapter conclusion. Hence, the synthesis is an interpretive process that results from the iterative data collection and takes into account the researchers experience of the barriers and enablers.

Chapter 9 consists of three sections. The first section (9.1) includes a framework with the barriers and enablers that result from synthesis. These are analyzed and discussed in this section. Consequently, the second section (9.2) presents the practical tool to support actors to accelerate the transition. The final section (9.3) is the chapter conclusion.

Table 5 *Barriers and enablers per subsystem after synthesis. Author's own work.*

Internal		External	
System actors		**(Natural) resources and provisioning services**	
Barriers	*Enablers*	*Barriers*	*Enablers*
* Actors have an attitude of negotiation rather than collaboration in the chain * Bias and assumptions about actors in the chain * Each actor approaches circularity differently; different goals and fragmented definition *The problem of the continuity of actors across a building's life cycle: not all actors profit from circularity in the long term * Insecurity about CCB or change due to shortage of knowledge on how components and products can affect circularity	* Increase of collaboration between chain actors * Each actor having the right preconditions and a perspective for action to be able to fulfill their role (clear role and responsibility) * Sharing knowledge and experiences * Stimuli in the chain	* Complexity of material supply chain	
		Technology, infrastructure and innovation level	
		Barriers	*Enablers*
			* Adoption of one language with methods , tools and KPIs for communication, monitoring and evaluation
		Governance, regulatory framework and political landscape	
		Barriers	*Enablers*
		* Vague long term ambitions and goals by the national government * A rigid relationship between the government and the market after tender processes	* Review and adjustment of the environmental performance of buildings (MPG) for a circular system * Collaboration through triple helix, in consortia and reporting from market parties to government
System values		**Activities performed by business and the market**	
Barriers	*Enablers*	*Barriers*	*Enablers*
	* Recognition of value of circular and biobased projects, both financially and from an ESG perspective * Upscaling industrial building for lower investment costs/ economies of scale * Industrial building with shorter production time results in higher financial rendement (quickly to use-phase)	* Circularity not rooted in business models *Long investment horizon, where higher short-term costs could threaten affordability * Guaranteeing and accounting for residual value of elements and materials	* Strong business case for CCB * Business model based on TCO, Including residual value and take-back guarantees * Increase of industrial building for economies of scale and shorter production time for faster returns from rent
System processes		**Patterns of behavior relating to meeting human and societal neeeds**	
Barriers	*Enablers*	*Barriers*	*Enablers*
* Processes are designed for traditional construction methods * Local integration and aesthetic quality of industrially produced houses	* Integrate flexibility in design to extent functional lifespan of a house * Design for disassembly * Pilots/living labs with clear ambitions, KPIs and evaluation	* Conservative mindset (internal organization or as organization in the chain) * Difficulty of changing behavior in the long term	* A crisis for behavioral change and adoption of innovation * Raising awareness and communicating the benefits of circularity * Make the end user ambassador of circular house

9.1 Analysis of synthesis

Table 4 shows the barriers and enablers that are overlapping either 1) in the theoretical and one of the empirical data sources (focus group and interviews) or 2) in both empirical data sources. Mainly in the empirical data collection, much emphasis is put on the barriers and enablers experienced in the internal system, the housing construction chain. These are mainly related to the actors in the chain and their roles in relation to each other. Even so, the system approach has resulted in an understanding of the evolving external landscape that impacts the housing construction chain. Accordingly, indications of various barriers and enablers in the external landscape came about throughout the various data collection phases.

The majority of the barriers and enablers are located in the internal system, in the *system actors* subsystem. The barriers relate to the current mindset of the actors in the chain, who focus on negotiation rather than collaboration; bias and assumptions about other actors; different goals and definitions of CCB and the problem of continuity of actors in the chain, so that not all actors in the current system benefit from circularity in the long term. The identified enablers in this subsystem are the increase of collaboration between chain actors; each actor having a clear role and responsibility in the chain; knowledge sharing and stimuli in the chain. Mainly collaboration between the chain actors is repeatedly mentioned as the most important enabler for this phase of the transition to a circular system.

Furthermore, a recurring barrier is that circularity is currently not rooted in business models. A strong business case for CCB is thereby identified as a crucial enabler. Moreover, awareness and behavioral change are frequently highlighted as enablers, which also results from the synthesis. Another recurring enabler is support from the national and local government with a clear roadmap that includes a vision and perspective on the medium term, which challenges the market actors for instance with the MPG. Furthermore, actors demand flexibility from governmental bodies to develop circular concepts based on flexibility and disassembly and that take into account the local environment and suitable aesthetics.

9.2 Tool: collaboration for a circular system based on CCB

Interpreting the results of the data and the synthesis, the actors in the socio-technical system would benefit from interventions in the *system actors* subsystem in this phase of the transition to a circular system. Each actor in the housing construction system has their own requirements, interests and goals. In the current linear chain, this manifests itself in a series of transactions and negotiations, which is a barrier in the transition to a circular system. In order to be able to practically implement interventions to support the actors, a concrete tool based on the barriers and enablers

in the *system actors* subsystem is developed. A crucial enabler that has been accentuated throughout all data collection, is collaboration between the chain actors, where each actor has their own role, responsibility and interests. Successful collaboration results in an integral approach, which is essential for CCB as it consists of a wide range of aspects to take into account. Hence, this section presents a tool for collaboration for a circular system based on CCB to support the chain actors. Actors in the housing construction chain could use this tool for housing projects or longer term collaborations, as a starting point to define roles and responsibilities.

The results from the actor analysis in chapter 5 are strengthened and validated during the empirical data collection, to better understand the role of each actor in a circular system. These are relevant insights for the development of the tool, as it is emphasized by the responding actors that the role, responsibility and interests of each actor must be clear. Accordingly, table 5 presents an overview of the role and interests of each actor in the chain into account, based on the results from the desk research as well as the insights from the empirical research. Furthermore, a column is added that shows how these actors could be incentivized to engage in a circular system based on CCB.

Actor	**Role in the housing construction chain**	**Interests**	**Incentive to engage in a circular system**
Municipality	Land issuance, land policy and other policies	Achieving policy goals, including in the area of sustainability. Monitoring the budget. Achieving or maintaining a liveable, economically vital and sustainable living and working environment	Residents' beliefs, political choices and political leadership, government policy and other municipalities
(Area) developer	Develop plans for the market in accordance with local principles and wishes from end users	Financially feasible and sustainable plan with a yield/margin which is higher than the land and construction costs	Municipalities, housing corporations, investors or end-users and own sustainability policy
Housing corporation	Provide and maintain social housing to rent it out on a long-term basis. Develops houses or buys houses from developers.	Provide (new) social housing and liveable neighborhoods as well as possible with available resources	Governmental policy, municipalities, developers, end users and their own sustainability policy
(Institutional) developer	Investing in housing projects for houses as assets in their fund. Contribute to more diverse housing supply in the private sector and mid rent.	Return on investment with a certain margin. Sustainability of portfolio projects is important	Investors (including pension funds), municipalities, developers, end users and their own sustainability policy
Architect	Making design plans and consulting during construction process	Financial continuity of the architectural firm, adding distinctive projects to their portfolio	The developer, corporation, investor, and end users
Contractor	Contractor of housing projects	Contract whereby a minimum profit and risk sum is realized. Managing risks in complex projects	The developer, the national government, the suppliers and own sustainability policy
Supplier	Contractor of contractors for the supply of products or materials	A minimum margin on delivered products or materials	The contractor and their own sustainability policy
End user	Resident or end user of the house	Affordable housing in relation to income. Sustainable and livable living environment	The developer, the housing corporation, the investor, the mortgage lender, other residents

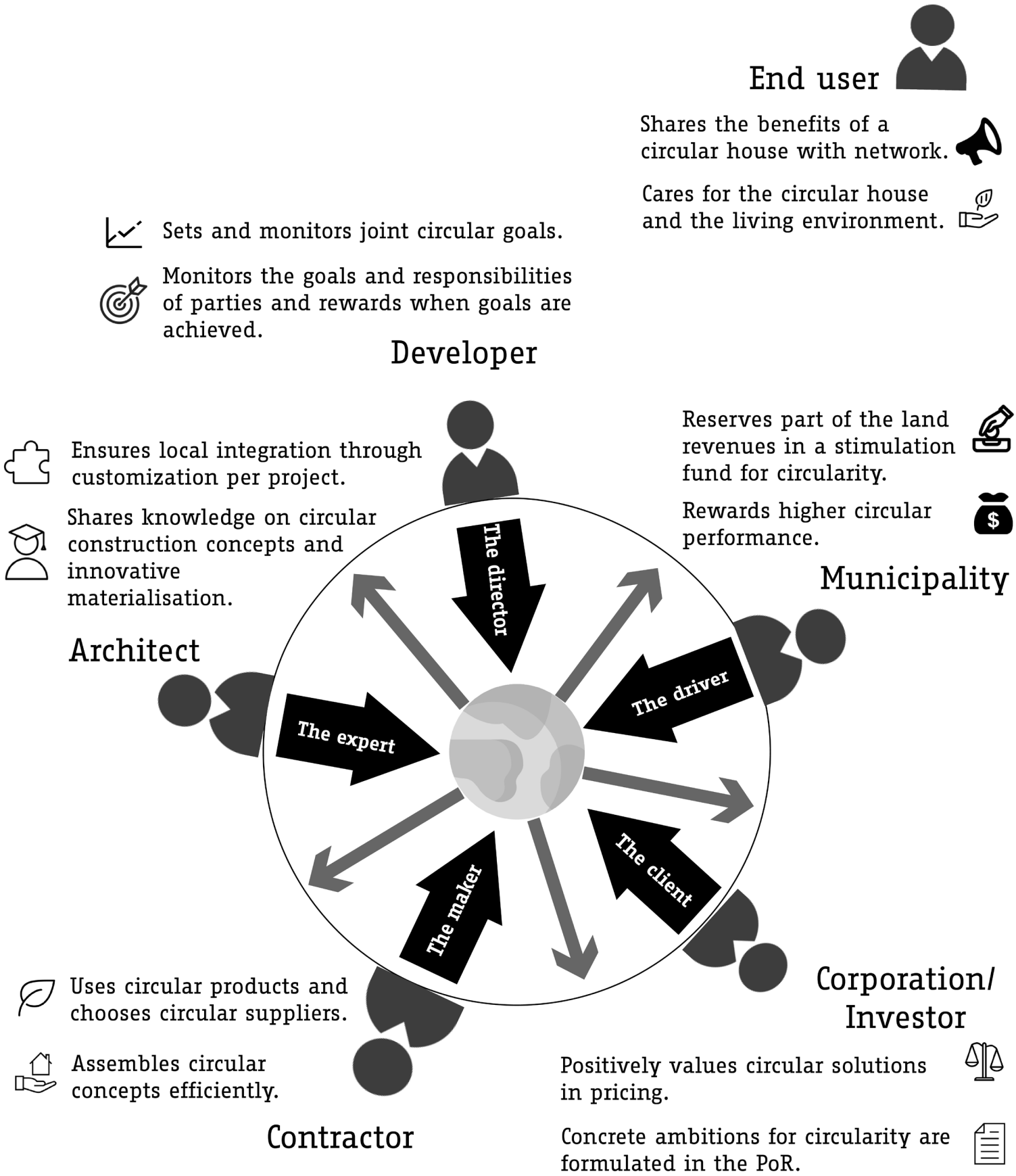
Table 6 *Role, interests and incentive to engage in a circular system per actor. Author's own work.*

The tool to support the key actors in the housing construction chain, the internal socio-technical system, to accelerate the transition to a circular system is visualized in figure 12. In this tool, each actor is positioned at a round table, illustrating that all actors are equal and no position is greater than another. The idea of the metaphorical round table is supported in the literature by Perkins (2003:2), illustrating King Arthur's round table:

"King Arthur knew that such a restless and fuming group could not help keep a kingdom in order, so he exercised a very simple idea: his knights would sit around a round table. No position would be greater than any other. Arthur wanted the upside of a thoughtful community. His knights would converse as equals. The round table not only symbolized this collaborative commitment but made it easier: at a round table, each knight sat within reasonable speaking distance of all the others. Of course, Arthur himself would have to sit somewhere at the table. But who happened to sit closer to him on that occasion would not be important."

The planet is placed in the middle of the table, as the future of that planet serves as an overarching focus point: CCB is perceived as a means to achieve the climate goals. The role and input of each actor in the housing construction chain is described, and the tool contains suggestions on how actors could take responsibility and advance the collaboration.

Figure 11 *Tool: collaboration for a circular system based on CCB. Author's own work.*



- **The municipality** is the driving force for CCB from (land) policy. Therefore, the municipality is conceptualized as the driver in this context. They need reflection of the market actors for suitable policies. The municipality has a strong position at the front of the process. The land price they demand is an essential factor in the business case. This offers opportunities to stimulate CCB, for instance by reserving a proportion of their revenues from land as a reward for the chain actors if circularity goals are reached. This offers support for a strong business case, which is often emphasized as a crucial enabler.

- **The developer** as a central client and contractor takes on the role of challenging and incentivizing other actors, but also pointing out their responsibilities. They have a central role in rewarding the chain actors when the circular goals are achieved. These goals are set and concretized at the beginning of the process on the basis of common interests and ambitions. Hence, the developer is conceptualized as the director.

- **The architect** is the expert in circular building concepts. They start from possibilities, including circular and biobased materials, flexibility and opportunities for disassembly. In comparison to the contractor, the architect starts from a theoretical perspective rather than practical. Accordingly, the architect ensures local integration and spatial quality by unique designs and customization per project. In addition to being a designer, the architect also consults and shares knowledge during the development and construction process. The architect proposes circular building concepts that suit the specific location of the client and their PoR. Hence, the architect is conceptualized as the expert.

- **The contractor** offers feasible, circular solutions. In comparison to the architect, the contractor focuses on practical knowledge and experience. Accordingly, the contractor assembles the circular concepts. Where possible, this process is industrial to take advantage of economies of scale and shorter production time. Moreover, the contractor incentivizes suppliers to deliver high-quality circular products. The contractor makes agreements with the suppliers on maintenance, take-back guarantees or Product-as-a-Service (PaaS). Hence, the contractor is conceptualized as the maker.

- **The housing corporation or (institutional) investor** as a client provides incentive for circular development by clearly defining what this means for them, and what they find important. The corporation or investor focuses on communicating concrete ambitions, rather than a list of requirements full of

details. Hence, the corporation or investor is conceptualized as the client. Furthermore, the corporation or investor is committed to ensure that all actors speak the same language and use the same tools for monitoring and evaluation.

- **The end user or resident** enjoys a high-quality, climate-proof house that suits their income. The developer and client engage in co-creation and knowledge sharing with the resident, in order to make the resident ambassador of their circular house.

9.3 Conclusion

This chapter sets out to answer the fifth subquestion: *Based on the synthesis outcomes, which interventions support actors in the socio-technical system, and where in the system could these be implemented?*

The synthesis of the outcomes of the literature review, focus group and interviews leads to multiple overlapping barriers and enablers from various data sources. The synthesis allows to identify these, and provides a basis for a practical tool with recommendations for interventions in the system to support the actors in the housing construction chain (the internal socio-technical system).

It results that in this phase of the transition, actors would mainly benefit from interventions in the *system actors* subsystem, as the barriers and enablers are repeatedly highlighted in the various forms of data collection. More specifically, a crucial factor in the transition to a circular system based on CCB is the collaboration between actors in the housing construction chain. The present-day housing construction chain is based on too many dependencies to unilaterally place the responsibility for CCB on a single actor. Therefore, all actors must make the transition from a linear to a circular system their common goal. This transition requires an integral approach, and increasing collaboration is at the core of a certain process. Each actor in the chain fulfills a role in the collaboration that accommodates their interests and besides, actors and stakeholders incentivize each other to engage in circular processes. The actors are metaphorically positioned at a round table where each actor is equal and there is room for greater collaboration.

10. Conclusion and recommendations

This chapter sets out to conclude this thesis by answering the main research question. This is done in the first section (10.1), after repeating and summarizing the five subquestions of this study. Accordingly, the next section (10.2) provides recommendations for practitioners in the housing construction system and recommendations for further research.

10.1 Conclusion

The housing construction system is in transition from one socio-technical system to another. The opportunities of CCB allow for flexibility, economies of scale and construction methods with lower environmental impact. Nonetheless, in the current linear system we will not be able to make CCB the standard in housing construction. Hence, a transition to a circular system is required. This transition is crucial to achieve the climate targets while continuing housing construction to fulfill the large housing task. The study has adopted a systems approach that understands housing construction as a socio-technical system. The housing construction system in transition is now in the *take-off phase* and this study aims to understand how the transition could reach the *breakthrough* and eventually the *stabilization phase.* The conceptual framework that is used allows for understanding where in the system interventions are relevant to bring about change and accelerate this transition.

The aim of this thesis was to understand what support actors in the housing construction system require to accelerate the transition to a circular system based on CCB. The study focuses on housing construction in the Netherlands. An integral approach is crucial in a circular system. Therefore, the study includes all phases of housing construction from land to planning, to design, construction, use and maintenance. This thesis focuses on the key actors that have an active role in housing development throughout these phases. The final objective is to deliver a practical tool that present-day actors in housing construction could use if they engage in CCB and wish to accelerate the transition to a circular system. Five subquestions are developed to eventually answer the main research question.

The first subquestion sets out to understand which actors, values and processes are present in the internal system of present-day housing construction and to explore the opportunities for CCB in this system. There are a variety of public and private actors in present-day housing construction. The key actors in the internal socio-technical system are municipalities, project developers, architects, contractors and suppliers, housing corporations and (institutional) investors. Each actor has their own interests, power and role in housing construction. Besides, there is an interplay between the

actors. Housing construction still predominantly occurs in a system based on a take-make-use-dispose approach. Nonetheless, the impact of this traditional system on the environmental, economic, social and technical domain illustrates that this way of working does not hold. An increasing number of stakeholders understand that the traditional, linear system exposes them to risks. The housing construction system is in motion towards a more sustainable system, as well as the external landscape that impacts the internal system. As a result of this first subquestion, two housing construction chains are developed as context-specific interpretations of the internal socio-technical system: the traditional, linear housing construction chain and the circular housing construction chain.

The **second, third and fourth subquestion** focus on the barriers and enablers that respectively are identified in the literature for transitioning to a circular system based on CCB in the built environment (subquestion 2); experienced by project developers (subquestion 3); experienced by actors in the internal socio-technical system and stakeholders in the external landscape (subquestion 4). For the acceleration of the transition, various barriers and enablers are identified in the socio-technical system through data collection with literature, a focus group and interviews. The literature review results in more enablers than barriers. The majority of the barriers are identified in the internal system, whereas the majority of the enablers are identified in one of the external subsystems. The results from the focus group mainly concern barriers and enablers in the internal system. During this session, collaboration between actors in the housing construction chain was indicated as the most important enabler. Moreover, there is a focus on the financial feasibility and a strong business case for CCB in the focus group session. The results from the interviews complement the results from the focus group, with a predominant focus on barriers and enablers related to the actors in the internal system, the importance of collaboration in the housing construction chain and financial viability.

The fifth subquestion concerns the synthesis of the data from the literature, focus group and the interviews. Furthermore, the fifth subquestion is concerned with the tool with interventions to support actors in the socio-technical system. It emerges that in this phase of the transition actors would mainly benefit from interventions in the *system actors* subsystem. All actors must make the transition from a linear to a circular system their common goal, and each actor should fulfill a role with corresponding tasks and responsibilities in the collaboration for the transition to a circular system. That is the basis for the tool: ‘collaboration for a circular system based on CCB’. The tool elaborates on the role that each actor in the chain could fulfill in a circular system, including the responsibilities and practical suggestions.

For this research, the following main research question was formulated:

What do actors in the internal socio-technical system require to accelerate the transition to a circular system based on circular and conceptual building, and how could these requirements be implemented?

The key findings of this study show that accelerating the transition to a circular system based on CCB is not particularly a technical challenge, as little barriers were identified on the technical capacity for this transition. Rather, it is a social challenge that requires cultural change in the housing construction sector. The success of the transition to a circular system based on CCB lies in the collaboration between actors in the housing construction chain. There are too many dependencies in the housing construction chain to unilaterally place the responsibility for circularity on one actor. Therefore, transactions and negotiations between the actors should make place for collaboration. More collaboration leads to an integral approach to transition to a circular system based on CCB and ultimately to achieving the climate targets.

10.2 Recommendations

The findings of this study shed new light on what the actors in housing construction require to accelerate the transition to a circular system based on CCB. The results make several contributions to the current literature. Firstly, the various forms of empirical data collection in this study gave insights into the barriers and enablers that practitioners currently experience. Hence, this study contributed to closing the gap between academic literature and practice. Secondly, the study has resulted in valuable insights on the *socio* rather than the *technical* part of the socio-technical transition. Lastly, the study offers a tool for practitioners with the aim to support them in accelerating the transition. The system approach has resulted in a wide range of insights. Therefore, there are various recommendations and opportunities for further research. These are categorized in this section as recommendations for practitioners and recommendations for further research.

Recommendations for practitioners

A valuable continuation of this research would be to implement the tool for collaboration in real world housing construction projects. Hence, it is recommended to practitioners in the housing construction chain to follow the roles and suggestions in the tool. The actors could find each other at a ‘round table’ at the start of a project, where each key actor in the housing construction chain is represented. As a starting point for the project, knowledge is shared, interests are expressed and developed into common goals and ambitions for CCB. Consequently, the roles are discussed and tasks and responsibilities are divided. Besides, agreements are made on the

responsibility for monitoring and evaluating the goals and ambitions throughout the project. Even though this research is largely based on insights from practitioners, it is important that the tool is used in the real context to validate, evaluate or refine the tool for further use.

Recommendations for further research

In terms of further (academic) research, a natural progression of this work is to further analyze the impact of the subsystems in the external landscape on CCB. This research has identified multiple barriers and enablers in the external landscape. This serves as a foundation to understand the external impact on the housing construction chain. Yet, this thesis deliberately focuses on the housing construction chain as the internal system in order to develop a practical tool for the actors in this system. Nonetheless, that leaves various other identified factors to be further explored.

Firstly, circular business models are highlighted by several respondents and important for a strong circular business case. Further research could elaborate on the opportunities for circular business models and how aspects like residual value could be taken into account and granted. Besides, further research could be conducted on innovations in quantifying circularity and environmental impact, including a focus on internalizing externalities. Thirdly, the impact of the regulatory framework on the transition could be further explored. Many respondents have stressed the importance of a clear roadmap with targets and regulations including the medium-term by the national government. Further research could lay a foundation for a certain roadmap. Fourthly, the opportunities for collaboration between the construction sector, agriculturalists and biologists could be explored in order to find synergies between the large environmental and economic challenges in agriculture and housing construction. Lastly, further research could elaborate on incentives for behavioral change, in order to better understand how individuals and organizations are willing to change their behavior in the long-term in favor of the environment.

11. Discussion

The discussion chapter consists of four sections. The first section (11.1) elaborates on the relevance of this study, in the context of other academic literature in the field. Accordingly, a section (11.2) is set out to explain the various perspectives on the transition to a circular system based on CCB that have emerged in this study. Subsequently, this thesis reflects on the conceptual framework from Iacovidou et al. (2021) that is adopted for this study (11.3). Fourthly, the limitations of this research are discussed (11.4). Finally, two alternative approaches to tackle complex systems are discussed (11.5).

11.1 Relevance of research

Due to this research, several novel insights emerge to the body of knowledge on transitions towards circular economy in the built environment. To date in academic literature, studies on circularity in housing construction have mainly focused on the building component level, quantifying the lifecycle analysis of buildings and materials and the definition of circularity in this context (Kanters, 2020). The study of Kanters (2020) elaborates on the barriers and drivers that different key actors experience-corresponding with this research. Nonetheless, their focus on the building scale and the application of CE principles in the design processes leads to a different focus of actors, ranging from a client with consultants, the municipality, expert consultants, contractors and subcontractors. They work from the hypothesis that “circular building design is successful when there is a supportive and ambitious client, an architect with the right skills set, available circular materials and a skilled contractor.” (Kanters, 2020: 3). However, taking the results from the actor analysis and the resulting housing construction chain into account, they leave a specification of the ‘client’ out of consideration and overlook the role of the developer. This is most probably due to the focus on the design phase. They do mention the real estate developer in their interview results (2020:13) presenting that architects discussed if the traditional role of the real estate developer should still exist in the circular economy. The argument here is that they do not have the intention to own the building for a long time and therefore might value decisions for circularity in building differently. This corresponds partly with the results from this study, where opportunities for chain integration are discussed, arguing for developers to be their own clients as investors. Furthermore, this study agrees that the traditional role of the real estate developer does not come into its own in a circular system. However, it is important to look for a novel role of the developer in a circular housing construction system, which this study has attempted to do with the tool for collaboration - where the developer has a relatively prominent role. In short, the systems approach that was adopted for this study, taking all phases of

housing construction into account, results in a different perspective on the key actors and allows for an elaboration of the role of these actors in a circular system.

Further, the outcomes of this study are compared to various other studies on barriers and enablers for circularity in the built environment in the existing body of literature. For instance, Giorgi et al. (2022) have done analysis on the present level of application of circularity strategies, identifying the related barriers and drivers through interviews with building stakeholders across five European countries. Their analysis focuses on the building level and the application of existing policies and practices of circular strategies. Their results lead to recommendations arguing for the need for greater international coordination of terms of policy, practices and enabling tools and stressing that improvements in both legislation and practices are needed. Their results overlook the importance of collaboration and knowledge sharing between actors in the housing construction chain, solely discussing the development of digital collaboration tools and platforms for collaboration for materials at the end of life stage. Their recommendations could be explained by their international focus rather than a local or nation-wide focus that this research adopted as a scale.

Bilal et al. (2020) stress that serious steps are required by all stakeholders of the building sector to improve the adoption of the circularity economy. Their main findings include that the lack of environmental regulations and laws drives the rest of the barriers to the circular economy. They have developed a mitigation framework for decision- and policymakers. This differs from this research as this research aims for supporting key actors in the housing construction chain, rather than decision- or policy makers in the external landscape.

To conclude, little attention has yet been paid to the barriers and enablers that key actors experience related to the process and organization of the internal socio-technical system. This study has studied all phases of housing construction with a systems approach. It reveals that focus on the ‘socio-’ part rather than the ‘technical’ part in socio-technical is of great importance in studies on socio-technical transitions to CE when it comes to the actors in the housing construction chain. Hence, the insights of this study as well of the tool for collaboration seem of added value to the existing body of knowledge.

11.2 Perspectives on the transition

Due to the systems approach, this research has led to a wide variety of barriers and enablers in the transition to a circular system based on CCB. This thesis focuses on the overlapping barriers and enablers from the literature, focus group and interviews. Yet, there are also discrepancies in the outcomes from the various sources.

Interestingly, external stakeholders generally identify enablers for accelerating the transition in the subsystems of the external landscape, for instance with a strong and suitable regulatory framework or innovative tools for quantification. These insights are gained during the literature review. This also results from the other studies discussed in section 11.1. There were various barriers and enablers from those outcomes that did not overlap with the outcomes from the focus group and the interviews. The actors in the housing construction chain are mainly concerned with the roles and relations of the chain actors. The focus is on accelerating the transition with collaboration, knowledge sharing and a working business case. Those insights mainly resulted from the focus group and the interviews.

To conclude, there are various perspectives on the transition to CCB. This research has focused on the perspective of the key actors in the housing construction chain, to understand what present-day practitioners require as support and in order to develop a practical tool. Nonetheless, it is important to take into account that there are multiple relevant ways to facilitate the transition to CCB. This is also stipulated in the conclusion section ‘recommendations for further research’ (10.2). Nonetheless, in all cases it is significant to explore the phase of the transition and to tailor interventions to the requirements of the targeted actors.

11.3 Reflection on the conceptual framework

For this research, the conceptual framework by Iacovidou et al. (2021) is adopted. They have developed this framework to propose a systems-based approach to transition to and understand the complexity of achieving a circular economy. Hence, the framework suits the systems approach of this research. In order to tailor the framework to the research at hand, the housing construction chain was developed to illustrate the internal system. This has been an important step to lay a foundation for the rest of this study, to give meaning to the interplay of actors, values and processes. Besides, it has been helpful in the communication to respondents in the empirical data collection part. Hence, it is recommended for other researchers that adopt this conceptual framework to study a transition to a circular economy to tailor the internal system to the specific context.

Furthermore, all participants acknowledged the conceptual framework, understanding the impact of the various external subsystems on the internal system and the interplay between the subsystems. During the data analysis and the coding, the external subsystems have turned out to be a complete whole in the landscape, being able to categorize the barriers and enablers accordingly. Concerning the internal subsystems, the ‘value’ subsystem has been the most difficult to capture and understand, most

probably due to its intangibility in comparison to actors and processes. Besides, the term ‘value’ is often used to explain underlying reasons or to express the importance or worth of something to someone. Yet, in this conceptual framework it concerns the impacts in one of the four domains (environment, economic, social and technical). Understanding the ‘value’ subsystem according to the impact in these domains has been helpful in the data analysis.

11.4 Limitations of research

First of all, circularity is a broad term that is understood in the current literature from multiple perspectives. Therefore, it has been a complex task to understand the current status of the transition from the existing body of literature in the theoretical phase of this study. Moreover, there have been many possible directions into exploring circularity in housing construction, ranging from a technical approach to a socio-cultural approach. Initially, this large scope made it difficult to find a clear focus point for the study. The transition to a circular system is a ‘wicked problem’; one that is hard to define and categorize. Hence, wicked problems are difficult to declare ‘solved’. This limitation exists throughout the body of literature on transitioning to a circular economy. This is supported by Campbell-Johntson et al. (2019) and Geels (2005) as discussed in chapter 2, explaining transitions as complex, non-linear, multi-level and multi-stakeholder processes, which makes it hardly possible to control them.

Lönngren & Svanström (2016) elaborate on wicked problems in the context of sustainable development, illustrating that researchers and students may feel overwhelmed by a wicked sustainability problem due to complexity, uncertainty and issues of justice, power and agency. A systems approach has been adopted to tackle the wicked nature of this challenge to a certain extent. Nonetheless, the results are broad. They cover the whole internal system and external landscape. Therefore, a large part of the study has an exploratory nature and the outcomes need further research to be refined with more detail. In order to concretize the outcomes, the direction of focusing specifically on the actors in the internal system has been chosen and the practical tool has been developed based on the barriers and enablers that they highlighted as currently important. Luckily, there was a clear direction in the perspectives of the respondents. Otherwise there should have been more emphasis on the order of importance of the indicated barriers and enablers in the data collection.

Nonetheless, Lönngren & Svanström (2016: 1) argue that the researcher might understand the wicked problem as a complex system, but still expects to be able to solve it by dividing it into seperate parts and solve each of these parts. A solution to (part of) a wicked problem will have consequences that will reach far into the future

and into distant parts of the system. In short, to not be able to solve the entire wicked problem and to not be able to oversee the consequences of the proposed solutions to one part of the problem, due to time and complex systems interactions, is a limitation that impacts this study to a large extent.

Thirdly, the generalizability of the results of this study is subject to certain limitations. For instance, the research has been tailored to the housing construction system in the Netherlands and therefore, the findings could not directly be generalized to other countries. Each country has their specific internal system and external landscape. But this also counts for area development within the Netherlands; the housing construction system is complex and differs per city or region. Each city or region has their own governance and structures. The housing construction chain that is proposed in this study is a simplified representation of the complex system it is. In order to take the topic of generalizability within the Netherlands into account respondents are contacted from organizations from various urban areas in the Netherlands, not focusing solely on Amsterdam or the Randstad area. Nonetheless, to increase external validity, a larger sample size representing the actor roles in the housing construction chain in various different regions in the Netherlands is desired.

11.5 Alternative approaches to tackle complex systems

The ‘system of systems approach’ is adopted for this study as it allows for exploring where in the system interventions are valuable in the current stage of the transition. Defining and exploring the various interconnected subsystems help to understand this. However, there are various other suitable theoretical approaches that seem appropriate to tackle complexities of this wicked problem.

The first example is the multicriteria decision analysis (MCDA). In this thesis a clear direction resulted from the respondents in what they required as support in this phase of the transition. Nonetheless, the MCDA procedure could have been applied to arrive at more rationally defensible decisions for interventions. It is based on identifying and evaluating alternatives on multiple explicit objectives (Schafer & Gallemore, 2016: 1652). Kiker et al. (2005) shows how the goals of MCDA are to organize data, make decision processes transparent and support decision makers. The method has similarities with Social Cost-Benefit Analysis, but MCDA does not require all criteria to be expressed in monetary units. This is helpful in adding together environmental, economic, sociopolitical and technological criteria to rank the importance of interventions to support decision makers. Schafer & Gallemore (2016: 1653) illustrate how MCDA involves four steps: (1) convene relevant stakeholders around an issue, (2) design a set of criteria upon which relevant alternatives to an issue can be evaluated, (3) evaluate those alternatives, and (4) aggregate the rankings into a

recommendation. The MCDA as a support tool helps to overcome bias and make holistic assessments.

The second example is the governance network approach. This approach concerns complex governance networks and acknowledges the existence of interdependence between organizations (Haffner & Elsinga, 2009). A certain approach seems suitable for the transition to a circular system based on CCB. Haffner & Elsinga (2009) have applied a combination of governance network approaches to the challenge of urban renewal in the Netherlands. Similar to urban renewal, it results from this study that the transition to a circular system seems also a matter of 'networking'. The actors in the housing construction chain have a joint responsibility in which they are dependent on each other. The transition would benefit from better collaboration. Haffner & Elsinga (2009) argue that acknowledgement of the complexity of networks would lead to more support for problem definitions and solutions. Accordingly, that would result in agreement about goals and win-win packages for actors. To add on to the recommendation for practitioners in the conclusion (section 10.2), it could be interesting to apply several governance network approaches to a case study where the actors use the tool (section 9.2) as a starting point for a housing construction process. This collaboration process could be reconstructed and governance network approaches could be applied. This helps to analyze the consequences of the proposed interventions. The outcomes could indicate whether the tool supports actors in accelerating the transition to a circular system based on CCB.

12. References

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Appendix A

Literature review

This section shows the outcomes of the literature review on barriers and enablers for circular construction in the built environment. The first table shows the barriers, a categorization, a (possible) enabler that could help overcome the barrier and the source - in order to understand from which knowledge field the barrier or enabler is derived. The second table shows the enablers, a similar categorization and the sources.

			Sources					
Barrier	**Subsystem**	**Internal/external**	**Academic**	**Consultancy research**	**Governmental bodies**	**Housing corporations/ investors**	**Contractors**	**Consortia**
Lack of interest to change behavior as traditional methods are stable	System actors, behavior and human/societal needs	Internal and external	Adams et al. (2017), Çetin et al. (2021)					
Conservative mindset	Behavior and human/societal needs	External	Mackenbach et al. (2020), Çetin et al. (2021)					
Limited awareness across supply chain	System actors	Internal	Adams et al. (2017), Bilal et al. (2020)					
A shortage of knowledge of how the design of buildings, components and products can affect their circularity	System processes	Internal	Adams et al. (2017), Bilal et al. (2020), Çetin et al. (2021)			Syntrus, 2021		
Lack of circular economy knowledge and fragmented definition	System actors	Internal	Adams et al. (2017), Campbell-Johnston (2019)			Van Driel & Büch, 2018		
Lack of incentive to design for end-of-life	System processes	Internal	Adams et al. (2017)					

Lack of consideration of end-of-life issues	System processes	Internal	Adams et al. (2017)					
Legal definition of waste restricts specific subsequent use	Regulatory	External						
Lack of policy measures and inconsistent rules to provide incentives for all stakeholders	Regulatory	External	Mackenbach et al. (2020), Bilal et al. (2020)					
Lack of market mechanisms for material recovery: well-recovered materials more expensive than virgin	Market/business	External	Adams et al. (2017), Bilal et al. (2020)					
Unclear financial/business case (finance is largely seen as a barrier rather than an enabler)	Market/business	External	Adams et al. (2017), Bilal et al. (2020), Çetin et al. (2021)	Acharya et al. (2018)				
Fragmented structure of supply chain and construction industry	System actors	Internal	Adams et al. (2017), Mackenbach et al. (2020)	Acharya et al. (2018)				
Complexity of buildings	System processes	Internal	Adams et al. (2017), Çetin et al. (2021)					
Low value of materials and products at end-of-life	Market	External	Adams et al. (2017), Campbell-Johnston (2019)	Carra & Magdani (2017),				
The problem of the continuity of actors across a building's life cycle	System actors	Internal	Häkkinen and Belloni, 2011			Van Driel & Büch, 2018		
The misalignment between business planning cycles and built environment asset life-cycles	Market	External	Mackenbach et al. (2020)	Acharya et al. (2018)				
Boom (hoogconjunctuur)	Market	External				Van Driel & Büch,		

phase in the construction sector hinders long term collaboration						2018		
The Dutch construction sector is project oriented and is challenged through tender processes	System processes	Internal		BTIC (2020)				
The construction industry thinks in the short term, while clients often maintain long-term thinking	System actors	Internal	Mackenbach et al. (2020)	BTIC (2020)				
Loss of ownership	System processes	Internal	Mackenbach et al. (2020)					
Lack of circular economy skills by employees in the supply chain	System actors	Internal	Bilal et al. (2020)					
Price of CLT is high since it has to be imported from (the near) abroad	Natural resources	External				Syntrus, 2021		
The realization costs for timber construction are 2.6 percent higher than for traditional construction	System values	Internal				Syntrus, 2021		

			Source					
Enabler	**Category**	**Internal/external**	**Academic**	**Consultancy research**	**Governmental bodies**	**Housing corporations/investors**	**Contractors**	**Consortia**
Articulating the value aspects of the circular economy	Market	External	Adams et al. (2018)					
Knowledge sharing on what circular construction means and is also clear what the legal requirements are and to which the measuring instruments apply.	Regulatory	External	Giorgi et al. (2022)		Rijksoverheid, 2021	Syntrus, 2021		

Clear business case based on a circular business model	Market	External	Adams et al. (2018, Carra & Magdani (2017), Giorgi et al. (2022), Çetin et al. (2021)			Van Driel & Büch, 2018		
Circular economy principle of systems thinking: identifying synergies and divergences	System processes	Internal	Adams et al. (2018),	Carra & Magdani (2017)				
Collaboration within the supply chain (housing corporations: where all partners commit to pre-defined circularity goals in order to obtain the intended profit. That way, a model of shared risks is created)	System actors	Internal	Adams et al. (2018), Giorgi et al. (2022)	Acharya et al. (2018), Carra & Magdani (2017)		Van Driel & Büch, 2018		
Collaboration through triple helix (public-private-third sector partnerships) and in consortia	Regulatory/ governance	External	Bilal et al. (2020), Çetin et al. (2021)		Rijksoverheid, 2021			AgendaStad (2022),
Information sharing capabilities (e.g. BIM)	Technological/innovation	External	Adams et al. (2018), Mhatre (2021), Giorgi et al. (2022), Oti-Sarpong, (2022)					Lente Akkoord, 2022
Material passports	Technological, regulatory	External	Mhatre et al. (2021), Giorgi et al. (2022)	Aertsen et al. (2022)	Rijksoverheid, 2021			BAMB (2016)
Awareness raising campaign	Behavior and human/societal needs	External	Adams et al. (2018), Bilal et al. (2020), Giorgi et al. (2022), Çetin et al. (2021)					
Development of enabling technologies to recover materials and take-back schemes	Technological	External	Adams et al. (2018), Çetin et al. (2021)	Carra & Magdani (2017)				
Development of higher value secondary markets	Market	External	Adams et al. (2018), Çetin et al. (2021)	Carra & Magdani (2017)	Rijksoverheid, 2021			
Design tools and guidance for disassembly and	Technological/innovatio	External	Adams et al. (2018),	Carra & Magdani				

flexibility	n			(2017),				
Sharing knowledge (best practice case studies) → also for policy makers for a beneficial regulatory environment “sharing knowledge in the triple helix”	System actors	Internal	Adams et al. (2018), Bilal et al. (2020)	Acharya et al. (2018)		Van Driel & Büch, 2018		
Leadership and first movers BTIC: The national government as a launching customer	Market, Regulatory/ governance	External	Bilal et al. (2020)	Acharya et al. (2018), BTIC (2020)		Van Driel & Büch, 2018		
Taxation and subsidies as economic instruments	Regulatory	External	Mathre et al. (2021), Bilal et al. (2020)					
Multi-level policy integration is needed to alter value chains to enable a greater reduction in material inputs and changes in actor behavior	Regulatory	External	Campbell-Johnston (2019), Mackenbach et al. (2020), Giorgi et al. (2022), Çetin et al. (2021)					
Basecamp for knowledge sharing on what circular construction means and on the legal requirements and measuring instruments apply.	Regulatory	External	Giorgi et al. (2022)		Rijksoverheid (2021)			
Municipal policy themes on circularity/climate neutrality as a tool	Regulatory	External				Van Driel & Büch, 2018		
Cost-neutrality in both investment and operation period in comparison to non-circular housing construction projects (allows for replicability)	System values	Internal				Van Driel & Büch, 2018		
Opportunities for low exploitation costs through passive energy solutions and healthy living environment (allows for higher investment opportunities)	System values	Internal				Van Driel & Büch, 2018		
Living lab as a testing ground for circular construction concepts for grip on innovation processes prior to changing regulation	System processes	Internal	Giorgi et al. (2022)			Van Driel & Büch, 2018		

Phasing of construction projects, with KPIs and evaluation moments per phase	System processes	Internal				Van Driel & Büch, 2018		
Press attention as a stimulus	Behavior and human/societal needs	External				Van Driel & Büch, 2018		
A valuation system in which residual value becomes an important component of the market value	Market	External				Van Driel & Büch, 2018		
Database for circular products and materials including knowledge and experiences from various parties	Technological/innovation	External	Giorgi et al. (2022)			Van Driel & Büch, 2018		
Review and adjustment of the environmental performance of buildings (MPG)	Regulatory/ governance	External		Rijksoverheid, 2021	RVO, 2021	Syntrus, 2021	Peschier, 2021	Lente Akkoord, 2019
All chain partners having the right preconditions and perspective for action, to be able to fulfill their role	System actors	Internal		BTIC (2022)				
Standard system of KPIs for measuring circularity in supply chain	Technological	External	Bilal et al. (2020)					
Specific requests through public tenders	Regulatory/ governance	External	Giorgi et al. (2022)					
Development and co-creation of disassemblable building products	Technological/innovation	External	Giorgi et al. (2022)					
Regulation 'CO2 levy industry' results in increase in the cost of concrete by 35 percent, while it has no effect on the cost price of biobased material (CLT)	Regulatory/ governance	External				Syntrus, 2021		
The value of sustainable buildings will increase over time, as a result of legislation, demand by investors and increasing resource scarcity	System values	Internal				Syntrus, 2021		

Appendix B

I. Focus group protocol

Focus group session

Participants

1. **Anouk Reintjens -** Development manager and theme leader ‘inclusive city’ AM
2. **Edwin Greuter -** (Civil) area developer AM Concepts
3. **Kitty Wu -** Area economist AM
4. **Maarten Markus -** Sustainability manager AM
5. **Steven Hupkens -** Project developer and leader ‘circular development’

Planning

Total duration: 2 hours

Introduction (total: 20 minutes)

1. Opening and introduction theme, research and research proposal (10 minutes)

To Do: Create PowerPoint presentation

1. Explaining the narrative of the housing construction chain and system (internal and external) (10 minutes)

To Do: Print the system on large paper (A0)

2. Explain the goal of the focus group: 1) to further explore topics from the literature and supplement it with practical experiences by hearing from different backgrounds. 2) Exploring important barriers and drivers in the system to further validate these in interviews (5 minutes)
3. Ask for consent to record the session and use the output and quotes from the session as empirical thesis data

Assignment 1 - Definitions (20 minutes)

1. The purpose is to understand the definitions of circular and conceptual building from the participants
2. One of the participants is asked to define circular building in the context of

housing construction. Subsequently, the other participants are asked to add on, or express a different view or definition.
3. Step 2 is repeated with the term ‘conceptual building’

Assignment 2 - Past, present, future (total: 30 minutes)
1. Each participant writes down their experiences on housing construction and CCB at the beginning of their career, now, and how they wish it will be in the future.
2. Each participant explains what they wrote in a round, there is room for little discussion if the scheduled time allows.

Assignment 3 - Exploratory assignment (total: 20 minutes)
1. As a transition from the first to the second assignment, ask the participants if they have already overcome a barrier from past to present.
2. Each participant writes down barriers (orange sticky note) and enablers (green sticky notes) to accelerate the transition to CCB.
3. They apply their sticky notes to the large printed paper with the system (internal in the chain or with one of the subsystems in the external landscape)

Assignment 4 - Discussion (total: 30 minutes)
1. Start a discussion based on the sticky notes. First, on the internal system focusing on the role of the actors. Secondly, the external subsystems and how these affect the internal system
2. Take opportunity to introduce factors from the literature that have not been brought up by the participants to explore their view
3. Investigate with the group whether there is a certain rank amongst the barriers and enablers (Note: this might be actor specific).

II. Results Assignment 3 - Exploratory Assignment


Extern systeem
Gedragspatronen (menselijke en maatschappelijke behoeften)
Bestuurlijke organen, regelgevend kader en politiek landschap
Technologie en innovatie
Client
Functie verandering
Architect
EU embodied carbon & taxonomy
Geld
Onzekerheid
Geopolitiek
MKBA
complexe en niet transparant leveringsketen
Ketenintegratie & partnerships
Co-making
Afhankelijkheid in de keten

Appendix C

Interview List

Name	Organization	Date	Function
1. Ruben Zonnevijlle	Dutch Green Building Council	12-04	Program manager
2. Joost Hoffman	Middle Of Our Street	13-4	Co-founder & director
3. Gertjan de Werk	Cirkelstad and City Deal CCB	19-04	Project leader City Deal CCB
4. Kes Brattinga	Syntrus Achmea	21-04	Strategy & research analyst
5. Sven Hillecamp and Jeroen Hollander	De Alliantie	21-04	Two interviewees: Projectmanager and Strategy & policy advisor
6. Roxan Roof	BrabantWonen	22-04	Projectmanager new-build
7. Guido Slokkers	Municipality of Rotterdam	02-05	Sustainable area development advisor
8. Jip van Grinsven	Alba Concepts	03-05	Consultant
9. Lianne Hulsebosch and Jeroen van der Waal	Municipality of Amsterdam	03-05	Two interviewees: Advisor and process manager sustainable area development and sustainability advisor
10. Jan Noorda	Lister Buildings	03-05	Senior development manager
11. Koen Haer	Ministry of the Interior and Kingdom Relations	04-05	Dealmaker and region advisor
12. Lizzy Butink	Dura Vermeer	05-05	Sustainability manager
13. Emma Lucassen	BAM Advies & Engineering	11-05	Sustainability advisor

Interview protocol

The presented protocol includes all possible interview questions, categorized according to the subsystems. Nonetheless, not all questions are relevant for all actors and stakeholders. Therefore, each respondent gets an adjusted version of interview questions with a semi-structured approach.

Name interviewee:
Organization:
Date:

Before the questions

- Thanking for cooperation
- Introduction of research and interviewers role in the research (MSc MADE thesis, AM intern)
- Asking for permission to record the interview
- Asking for permission to use direct quotes from the interview (ask again after the interview)
- Indicate the duration of the interview

General questions

1) What is your function within *organization*?
2) Could you describe the role of *organization* in the development of housing?

This interview is about accelerating the transition to a circular system in housing construction. We are faced with a major housing development task that requires a lot of construction, quickly, but also climate-proof and affordably. I believe that the only way we can do that is with a different way of working, in a circular system. The question is, how are we going to get there and how are we going to get there quickly? What do the parties need? That is the core of my research, and I am currently exploring this with a variety of stakeholders.

- Definitions-

As a start, I would like to hear your definitions of two concepts, with the development of new-build housing in mind.

3) What is your definition of circular housing construction?

4) What is your definition of conceptual housing construction?

- Internal system -

5) What makes circular or conceptual construction interesting for *organization?*
6) What do you think circular and conceptual buildings will look like in the future?
7) What do you think is the biggest challenge for the housing construction chain to accelerate the transition to a circular system?
8) What is the biggest challenge for *organization* to transition to a circular system?
9) What is *organization*'s incentive to participate in circular or conceptual development? Is that incentive predominantly economic, technical, social or environmental?
10) Do you see opportunities for CCB for specifically affordable housing?
11) Do you also see social goals linked to CCB?
12) What is the difference between owner-occupied and rental housing for a circular system in housing development?
13) In a circular business model, the residual value of materials or elements is included. Do you see a way that *organization* can take advantage of this residual value?
14) What is the role of *organization* in relation to other partners in the chain?
15) Which partner(s) within the chain do you think play an important role in accelerating the transition to CCB?
16) What do you think of the current way of collaborating in the chain?
17) How important is collaboration between the chain actors for accelerating the transition to a circular system?
18) Could new forms of cooperation between partners in the chain accelerate the transition to CCB?
19) What could such a collaboration look like? (Mention an example dynamic distribution model)
20) What do you think about knowledge sharing within the chain?
21) What do you think of living lab/pilot constructions?

- External landscape -

Natural Resources

22) To what extent do material availability and costs play a role in your choices for the concept?

23) Where do the materials come from?

Governance, regulation, politics

24) Are current government regulations restrictive or rewarding?
25) What are you missing from the central government/national politics to accelerate the transition to CCB? What do you need from them? (or what do they need from the market)
26) The City Deal CCB was initiated by the BZK, are you satisfied with the role that the BZK plays in this? or does it mainly come down to the market?

Market and business

27) Developing circular business models is important to build a sound business case on CCB. Do you agree that, with such a CBM, circular and conceptual construction can contribute to the rapid development of affordable housing?
28) What do you think about houses as product-as-a-service, with a certain return guarantee?
29) What is required for that?
30) Does *organization* take the notion of TCO into account?
31) Which stakeholders have a role in that?
32) What role could banks play in financing CCB?

Technology, infrastructure, innovation level

33) Digitization is increasingly emerging within conceptual building, for example working with parametric models. What innovation in digitization would be more beneficial?
34) Are there other innovative instruments that can have a positive impact on accelerating the transition to CCB?

Behavior and human/societal needs

35) Is there wide support for the transition to a circular system in your organization?
36) How is the support from the management?
37) If not, what do you think could help to change their behavior in this sense?
38) What is the role of the end user of the house in this transition?

39) Are there other things that I did not mention yet that you think have an impact on the acceleration of the transition towards CCB?

Appendix D

Thematic analysis and coding

Phase	Description
1 Familiarization	The transcripts are uploaded and read in ATLAS.ti
2 Coding	Meaningful sentences and ideas are highlighted. These are ‘quotations’. Each quotation is named with a code.
3 Generating themes	In the end, a code has multiple quotations. Each code is seen as a theme. Themes are assigned to an internal or external subsystem.
4 Reviewing themes	After the interviews, the first themes from the focus group are reviewed and quotations are added to these themes, or new themes arise.
5 Defining and re-naming themes	1) All data is reviewed as well as all generated themes and their categorization in internal or external subsystems. 2) Possibly, themes are merged and/or re-named, to refine each theme. 3) The quotations per theme are reviewed to highlight and distinct barriers from enablers.
6 Writing up	1) A report with the quotations per theme and subsystem is generated from ATLAS.ti 2) Captivating quotes and examples are identified in the quotations. 3) The result section of the chapters are written following the themes, based on the barriers and enablers and including quotes and examples 4) The barriers and enablers are captured per subsystem in the clustered summary of results