The circular economy transition:
Barriers to building with biobased materials

Exploratory research on the current barriers to the use of biobased building materials in the Netherlands.

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Colophon

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Summary

The construction sector is a major contributor to carbon emissions, which must be reduced due to climate issues. We are also getting closer and closer to the moment when certain materials will run out because construction mostly uses exhaustible raw materials. In addition, the Netherlands has to deal with a housing shortage which makes it necessary to build and farmers have to stop because of their pressure on the climate. "Biobased construction" is (partly) a solution to many different problems mentioned above. "Biobased construction" is the use of building materials made from fungi, plants, bacteria and animal material, which are grown, harvested, used and reused responsibly such as wood, wool and straw. These materials can be grown indefinitely so are regrowable and store carbon. The materials are also reusable and very lightweight. In addition, building with biobased building materials has other benefits such as health and biodiversity.

Nevertheless, biobased building materials are built to a limited extent in the Netherlands. This research aims to find out why there is limited use of biobased building materials. This has led to the following main question: “What are the current barriers to the adoption of biobased materials and how do they influence uptake in the Netherlands?”. It was investigated using qualitative, inductive, and exploratory research through 12 interviews and document analysis, which were coded thematically to answer this. The basis of the interviewees' determination is the design of a biobased chain based on a Life Cycle Assessment (LCA).

The following conclusion emerged from this research, the socio-cultural factors that form a barrier to the adoption of biobased building materials are reputation, leadership, traditional lobby, education and Dutch culture. Institutionally, certification, the euro and building code, the land-use plan, measurement methods and government form a barrier. Economically, affordability is a barrier and there are barriers in the chain such as the 'chicken-egg story' and staff shortages. There are also technical barriers such as specifications, the uncertainty of maintaining biobased materials, designing traditionally and the lack of data. Based on this research, several solutions can be recommended. In addition, this research largely serves as a basis for further research, for example, into possible solutions.

Keywords: Biobased materials, building sector, circularity, buildings, barriers

Preface

Dear reader,

"Biobased construction", in my view, is a solution to many, major, current, social problems such as the carbon problem, the housing shortage, the climate problem, the problem of farmers etc. Yet biobased construction is still limited and this raised big questions for me. Hence, I researched the barriers in biobased construction, hoping to write good advice and solutions afterwards.

I wrote this thesis from my master's degree in Spatial Planning and specialisation Planning, Land and Real Estate Development at Radboud University in Nijmegen. I also did this research for Alba Concepts. Sustainability and society have interested me since childhood. Later, my interest in buildings and areas was added, which makes the subject of biobased building a perfect fit with my interests. When I came across the subject of biobased construction, I was immediately excited by the many solutions it offers. This thesis is for anyone interested in sustainability and specifically in construction.

I would like to thank my supervisor, Iulian Barba Lata from Radboud University for his guidance and support while writing the thesis. Great that you had the patience to explain everything to me so well and sometimes if necessary more than once. I would like to thank Yaël Ben-Basat for her good guidance and confirmation that I sometimes needed to have enough confidence in myself to continue. I would also like to thank her for her help in approaching the interviewees and advice in analysing the data. I would also like to thank my other colleagues at Alba Concepts for the interesting conversations and sociability. I would also like to thank the interviewees who participated in the interviews and shared their valuable knowledge with me. Finally, I would like to thank my friend, family, friends and cat for supporting me throughout the process.

I hope you enjoy reading.

Jans van den Eijnde
Sint-Michielsgestel, 16 June 2023

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1 Introduction

1.1 Research problem

Due to overconsumption of raw materials, our planet is running out of resources. We need to move from a linear to a circular economy (hereafter named CE). This is an economy without waste where all products remain of value. The EU aims to be climate neutral by 2050 and part of this is CE. To achieve this, a new action plan, Circular Economy Action Plan (CEAP), was adopted in March 2020 (European Commission, 2023). The construction sector is a priority to make this transition because it is a fundamental sector, at around 9% of the European GDP (European Commission, 2018), and because it produces the highest quantity of waste in the EU (Eurostat, 2016). The Dutch government developed its own strategy: The Netherlands Circular by 2050 (Het ministerie van Infrastructuur en Milieu; Het ministerie van Economische Zaken, 2016). Part of the implementation program is the transition agenda to a circular construction economy where part of the focus is on biobased construction. In addition to running out of resources, global warming from carbon emissions also plays a role. In recent decades, fossil carbon emissions have risen sharply and, as a result, the earth's temperature has risen with consequences such as the Arctic ice cap rising and sea levels rising. Given that the built environment is responsible for over 39% of global greenhouse gas emissions, there are opportunities here to reduce the carbon footprint (United Nations Environment Programme, 2020). Besides these global climate problems, there is a housing shortage in the Netherlands (Ministerie van Binnenlandse Zaken en Koninkrijksrelaties, sd). Because of this housing shortage, 900,000 houses need to be built in the Netherlands by 2030. As mentioned earlier, the current way of building has a major impact on the climate. This is where the two policy goals, climate goals and housing goals, clash. This problem statement is briefly formulated as follows:

"Current carbon emissions and the use of exhaustible materials in building are causing climate problems and continuing to build this way is not possible but with the current housing shortage in the Netherlands it is necessary."

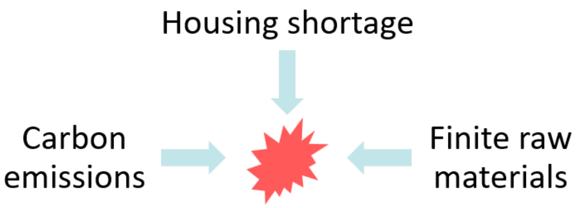

Figure 1 Visualisation of problem

Figure 2 (on the following page) shows a carbon-based design framework with the option to keep a structure within the carbon emissions budget. The framework consists of three streams of options namely prevention (1), value preservation (2) and value creation (3). Prevention is partly possible by subdividing buildings but this cannot completely solve the housing shortage, houses need to be added (Ministerie van Binnenlandse Zaken en Koninkrijksrelaties, sd). Another option is to deploy high-value reuse of materials but research shows this can accommodate at most 20% of demand (De circulaire bouweconomie, 2022). This research focuses on value creation which option consists of two sub-solutions namely biobased building and low-carbon building because these ways can make the biggest contribution to reducing carbon emissions. The major contribution of biobased construction lies in the fact that these building materials, besides not emitting carbon emissions, also store carbon emissions. This ensures negative carbon emissions when using these materials. Several researchers have shown that storing carbon leads to positive long-term effects (Eriksson, et al., 2007; Pilli, Fiorese, & Grassi, 2015; Brunet-Navarro, Jochheim, & Muys, 2016).

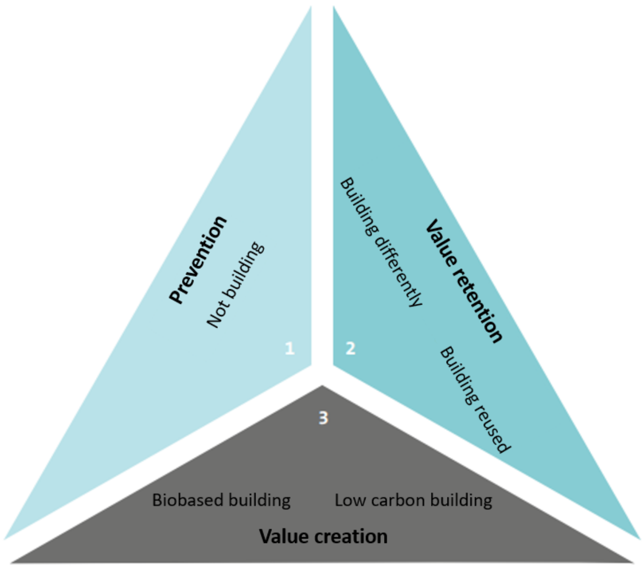

Figure 2 Carbon based design framework (Schotte & Ben-Basat, 2023), translation of author

A possible way to solve this problem is to use biobased building materials because these materials emit less carbon, create storage and are inexhaustible. Currently, the transition from a linear to a circular economy is on its way and part of this is the transition to biobased building materials in the construction sector.

1.2 Research aim and research question(s)

In this section, the purpose of the study, an intervention question and the research question are stated. The research question is supported by four sub-questions.

This study aims to explore the barriers to biobased building in the Netherlands. This research aims to provide an overview of the barriers to biobased building in the Netherlands. These barriers provide a starting point for solutions in stimulating biobased building to ultimately reduce the sector's emissions from the built environment. This research can also create more awareness of the aspects that can stimulate the transition to biobased construction. The research for the internship company aims to have solutions and a better understanding of the barriers to the use of biobased building materials. This research is useful in the advice they give to different parties. Due to this, they can better respond to these barriers and stimulate companies/governments to use biobased building materials. To achieve this aim, an intervention question has been drawn up, which reads as follows:

"In what way(s) can the use of biobased materials in the building sector be stimulated?"

To answer this intervention question (IQ) with solutions to promote biobased building materials in the construction industry, the current situation must first be explored. As shown in Figure 3, for a process to be successful there must be few or no barriers and instead, there must be opportunities. Therefore, the following exploratory research question (RQ) is designed to focus on the barriers:

"What are the current barriers to the adoption of biobased materials and how do they influence uptake in the Netherlands?"

To answer this research question, four sub-questions were developed. These are formulated based on the concepts from the conceptual model. They are as follows:

1. How are socio-cultural factors influencing the use of biobased building materials?
2. How are technical factors influencing the use of biobased building materials?
3. How are economic factors influencing the use of biobased building materials?
4. How are institutional factors influencing the use of biobased building materials?

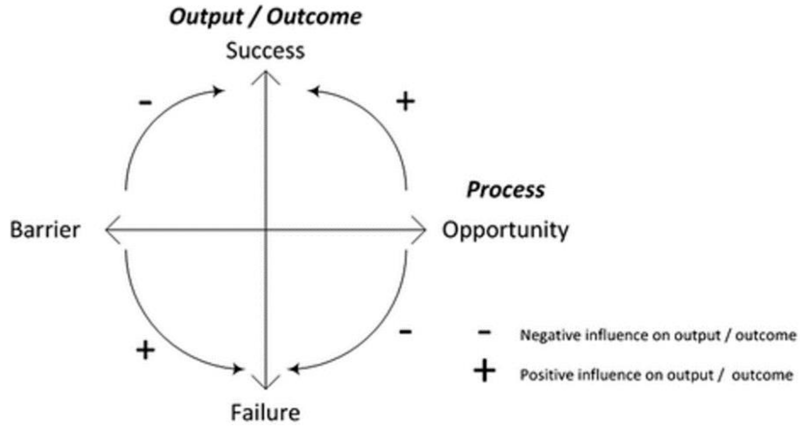

Figure 3 'Barriers' on the continuum of process and output/ outcome (Biesbroek, Klostermann, Termeer, & Kabat, 2013)

1.3 Relevance

1.3.1 Scientific relevance

There has been a tremendous amount of research on the CE and the transition to it, including barriers in the transition to a CE. This has been researched from different perspectives, such as organizations' perspectives (Masi, Kumar, Garza-Reyes, & Godsell, 2018; Liu & Bai, 2014), industrial perspective (Oghazi & Mostaghel, 2018) and small and medium enterprises' perspectives (Rizos, et al., 2016). Habold (2020) conducted an exploratory study of the barriers experienced in obtaining and managing national government incentives for circular innovation. This research is based on Tura's framework (2018) with barriers and drivers of the CE. There have also been several studies on barriers in the transition to a circular economy in the construction sector (Bilal, Khan, Thaheem, & Nasir, 2019; Charef, Morel, & Rakhshan, 2021; Giorgi, et al., 2022; Wuni, 2022). Less research has been done on the barriers to the use of biobased building materials, although this has been done in Sweden (Markström, Bystedt, Fredriksson, & Sandberg, 2016; Markström, Bystedt, Fredriksson, & Sandberg, 2016) and Switzerland (Göswein, Arehart, Phan-Huy, Pomponi, & Habert, 2022). A research gap was found in research on the barriers to the use of biobased building materials in the Netherlands. This exploratory research can serve as a trigger for further research on the barriers or solutions to the use of biobased building materials.

1.3.2 Societal relevance

According to Van Thiel (2014), social relevance implies that the research expects to contribute to solving social problems or questions. This research has a significant social relevance as it addresses both macro-level and micro-level problems. At the macro-level, the problem consists of the use of exhaustible resources and global warming and at the micro-level, the housing shortage. Both problems have a great social aspect as they affect the entire society. Researching ways to encourage the use of biobased building materials can help solve these problems. Policy documents from governments also show that the subject of biobased building is playing out in the Netherlands. For instance, the European

Union wants to be climate-neutral by 2050 and part of this is to increase the CE and reduce global warming (European Commission, 2023). The Dutch government has translated this into its approach to becoming circular, focusing on the use of biobased building materials (Het ministerie van Infrastructuur en Milieu; Het ministerie van Economische Zaken, 2016). This research contributes to the discovery of the barriers to the use of biobased building materials, which can be used to remove these barriers and increase the use of biobased building materials, thus solving the problems identified.

1.3.3 Practical relevance

This research was written in conjunction with an internship at Alba Concepts, a consultancy focused on management and project development where real estate, sustainability, strategy and finance come together. Alba Concepts focuses on circular construction and makes this measurable and concrete (Alba Concepts, 2023). The use of biobased building materials is part of circular construction and for Alba Concepts, the barriers in this are important to be able to look for solutions. When advising on circular and biobased building, people need to be aware of the barriers to overcome. This research is going to overcome the barriers and provide better advice.

1.4 Reading guide

This master's thesis consists of 6 chapters, excluding the references (chapter 7) and the appendices (chapter 8). The first chapter consists of the introduction stating the problem, which leads to a research aim and question with sub-questions. It also explains the scientific, social and practical relevance of the research. Chapter 2 presents the literature review, the theoretical framework and the operationalisation of the theoretical concepts. Chapter 3 presents the methodology through research strategy, research methods, data collection, the data analysis. In support of this methodology, validity and reliability are explained in this chapter. Chapter 4 presents the results of the study. In chapter 5, the discussion answers the sub questions. In conclusion, chapter 6 answers the main question and the intervention question. It also contains the recommendation based on this research to practitioners and the client, Alba Concepts. Last, there is a reflection of the research.

2 Literature review and theoretical framework

This chapter presents the literature review and theoretical framework. The literature review reflected on the existing literature on biobased construction and the barriers therein. This review served as a basis for the theoretical framework. Later in the chapter, the aspects of the theoretical framework are operationalised, and this leads to a conceptual model.

2.1 Literature review

This subchapter presents the current literature related to the barriers to biobased building. The chapter is organized this way it starts with literature somewhat further from this research and increasingly related to this research shown in Figure 4, for example, it begins with barriers in the transition to a circular economy and ends with studies on barriers to biobased building in Europe.

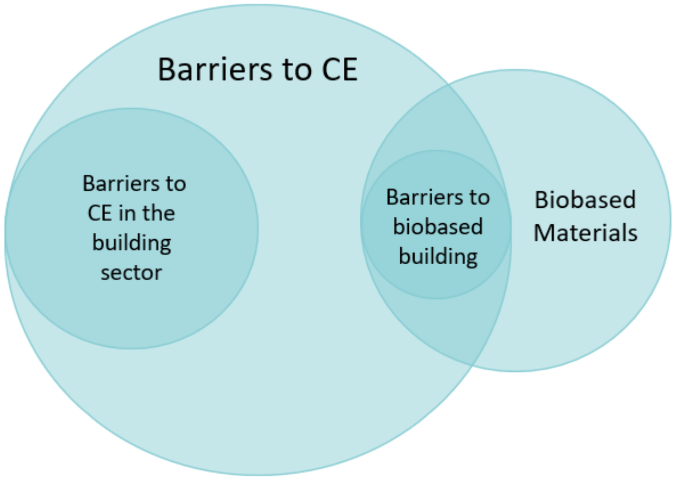

Figure 4 Overview literature review

2.1.1 Barriers to CE

There has been a lot of research done about strategies and tools for the transition to a CE but the economy is still largely linear and not circular therefore more and more research is being done on the drivers and barriers. There is been research done on this from different perspectives, such as organizations' perspectives (Masi, Kumar, Garza-Reyes, & Godsell, 2018; Liu & Bai, 2014), industrial perspective (Oghazi & Mostaghel, 2018) and small and medium enterprises' perspectives (Rizos, et al., 2016). Habold (2020) conducted an exploratory study of the barriers experienced in obtaining and managing national government incentives for circular innovation, shown in Figure 5.

Categories	Barriers
Economic	• High costs and lack of financial capability and support • Lack of tools and methods to measure (long-term) benefits of CE projects.
Social	• Lack of social awareness and uncertainty of consumer responsiveness and demand • Lack of market mechanisms for recovery • Lack of clear incentives.
Political and institutional	• Complex and overlapping regulation • Lack of governmental support • Lack of CE know-how of political decision-makers.
Technological and informational	• Lack of information and knowledge • Lack of technologies and technical skills
Supply chain	• Lack of network support and partners • Strong industrial focus on linear models • Lack of collaboration and resources
Organisational factors.	• Incompatibility with existing (linear) operations and development targets • Silo thinking and fear of risks • Conflicts with existing business culture and lack of internal cooperation • Heavy organisational hierarchy and lack of management support • Lack of CE knowledge and skills

Figure 5 Framework of CE barriers from Tura adjusted by Habold (Habold, 2020)

This research is based on Tura's framework (2018) with barriers and drivers of the CE which includes seven distinct areas (Table 1) created using 36 qualitative semi-structured interviews. The cause for this research was a lack of a complete overview of all the barriers and drivers of the CE (Tura, et al., 2018). Hart et al. (2019) researched the obstacles and drivers of CE in the UK building environment. This research results in the conclusion that technological and regulatory developments will not be enough to overcome barriers but that new business models and a change in stakeholders' behaviours are needed.

Table 1 Original framework barriers for CE from Tura (2018)

Categories	Barriers
Economic	▪ High initial investment costs ▪ Scarcity of raw material, assets or infrastructure ▪ Dominance of economic indicators in decision making
Social	▪ Scarcity of raw material, assets or infrastructure ▪ Conservativeness in business practices ▪ Lacking or uncertain customer needs
Institutional	▪ Region-specific laws and regulations against CE solutions ▪ Conflicts of interest and fluctuations in taxes and governmental subsidies - high future uncertainty
Technological and informational	▪ Increased technical difficulty in handling CE material flows (lower homogeneity of raw material) ▪ Lack of compatible technologies and high technological uncertainty ▪ Lack of practices and systems for collecting, sharing and utilizing CE information
Supply chain	▪ Conflict of interest, values and modes of operation between different stakeholders ▪ Conflict of interest, values and modes of operation between different stakeholders ▪ Validating and verifying all environmental effects is a challenge for transparency and analytics
Organizational	▪ Incompatibility with existing (linear) operations and development targets ▪ Conflicts with existing business culture ▪ Silo thinking and fear of risks

2.1.2 Barriers to CE in the building sector

There has been research about barriers in the building sector of the transition from a linear economy to a CE. In 2019, research has been conducted on the current state and barriers to transition from a linear economy to a CE of the construction sector in developing countries. Here, the model was used for CE barriers. Detailed literature research revealed 72 significant indicators for CE assessment from research from 2010 to 2019 and reduced to 64 factors by taking out repetition and 24 indicators using qualitative content analysis with expert interviews. With questionnaire surveys, the researchers explored the barriers and created a mitigation framework (Bilal, Khan, Thaheem, & Nasir, 2019).

Table 2 Barriers for CE according to Bilal et al (2019)

Categories	Barriers
	▪ Lack of environmental regulations and laws
	▪ Lack of customer/ public awareness
	▪ Lack of support/backing from public institutions
	▪ Inadequate financial resources

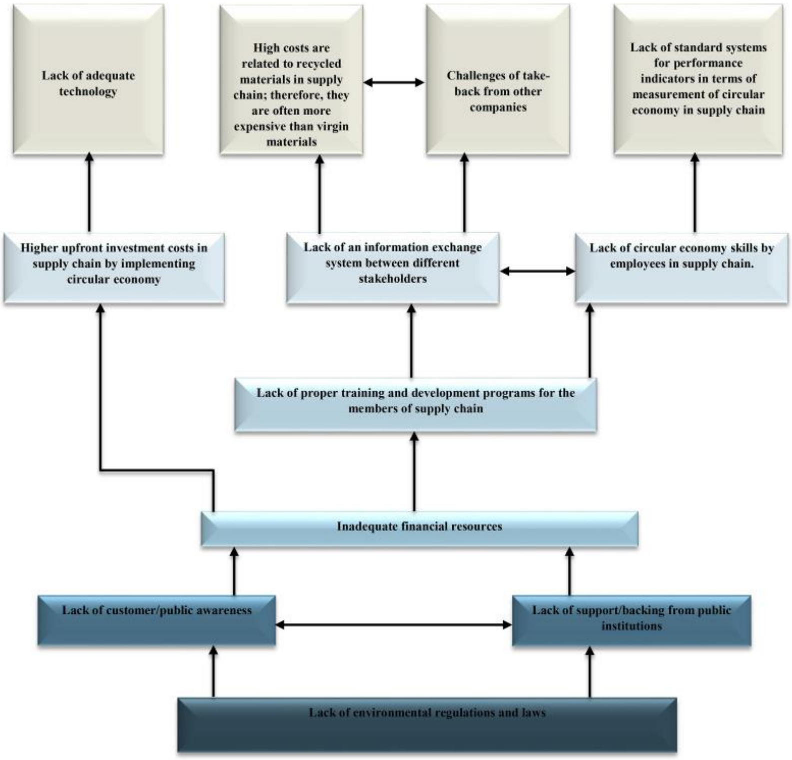

Figure 6 ISM model for CE barriers (Bilal, Khan, Thaheem, & Nasir, 2019)

Another study was done on the barriers to implementing CE in the construction industry focusing on implementing sustainable designs and approaches. This research is based on data from a critical review of journal papers on the barriers to implementing sustainable designs and approaches. This is aimed at designs that do not end in demolition (Charef, Morel, & Rakhshan, 2021).

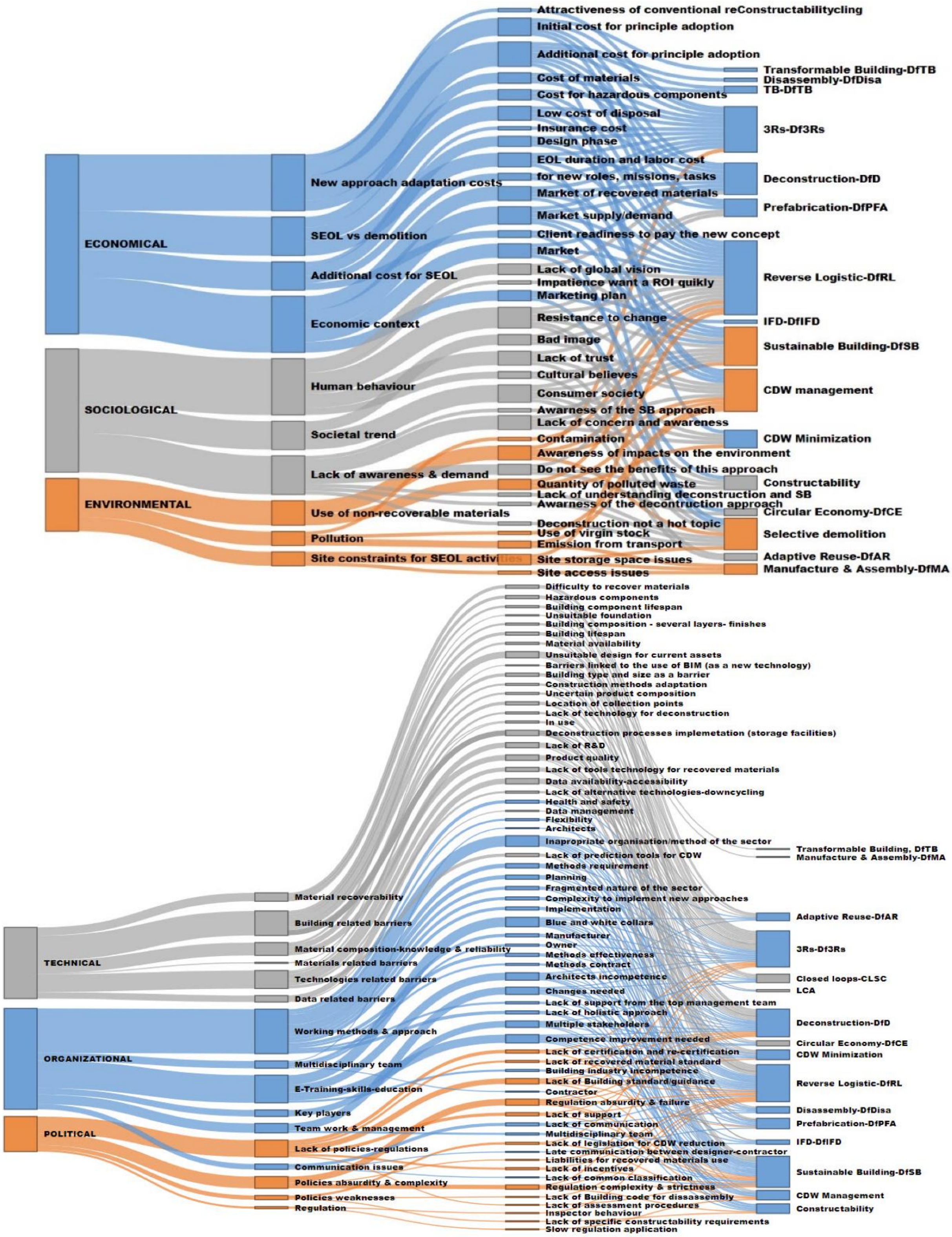

Figure 7 Outline of results of sociological, economic, environmental, technical, organisational and political barriers (Charef, Morel, & Rakhshan, 2021)

There is also research done about the drivers and barriers towards a circular economy in the building sector by analysing policies and practices in five European countries including the Netherlands. This research was done in three key fields namely; resource and waste management, design for a reversible building, and business for the networking of operators in the construction value chain and is therefore too specific and not suitable as a framework (Giorgi, et al., 2022).

Wuni (2022) did also research the barriers to the circular economy adoption in the construction industry. Using a systemic review of 53 relevant studies between 2018 and 2022, 95 barriers were identified. These are divided into 11 typologies namely cultural, market, knowledge, financial, management, regulatory, technological, supply chain, stakeholder, technical and organisational barriers, shown below. These financial, knowledge, regulatory, managerial and supply chain barriers are the most persistent.

Table 3 Barriers for CE in the building sector according to Wuni (2022)

Typologies	**Barriers**
Cultural barriers	▪ Hesitant company culture and change resistance ▪ Lack of interest in recycled and remanufactured products ▪ Reluctance and risk aversion of construction stakeholders ▪ Perceived poor quality of refurbished and recycled products ▪ Preferences of virgin construction materials over reused and recycled products ▪ Absence of CE and sustainable cultural behaviour
Market barriers	▪ Lack of market pressure and competition ▪ Uncertain market demand for refurbished, remanufactured, and recycled products ▪ Immaturity of market and relevant technologies ▪ Limited availability of recycled materials and reused products ▪ Lack of market mechanisms for waste recovery ▪ Poor demand for environmentally superior technologies ▪ Lack of high-quality recycled materials and products ▪ Lack of a market for second-hand materials and products
Knowledge barriers	▪ Lack of CE knowledge, technical capabilities, and expertise in construction ▪ Limited stakeholder awareness of circular materials, products, services, and strategies ▪ Limited CE awareness across the construction supply chain network ▪ Lack of appropriate CE training, development programs, and technical support for supply chain members ▪ Lack of data and information of circular construction materials, products, and services ▪ Insufficient understanding of the benefits of circular materials and products ▪ Unavailability of skilled labour and manpower ▪ Client ignorance of CE ▪ Lack of environmental education and culture of environmental protection ▪ Difficulties of measuring CE project and business benefits in construction
Financial barriers	▪ Higher upfront investment costs ▪ Lack of funding for circular business models ▪ Lack of capital and financial resources ▪ Lack of economic benefits in the short run ▪ Low prices of virgin materials ▪ Unpredictable financial returns and economic savings ▪ High cost of eco-friendly materials and products ▪ Unclear financial business case for CE in construction ▪ Higher prices of recycled materials and products ▪ High cost of establishing eco-industrial chains ▪ Split incentives ▪ Higher cost of waste collection and segregation ▪ Lack of economic viability of circular business models ▪ Significant transaction and production costs of CE ▪ Low value of material and products at end of life
Management barriers	▪ Lack of top management commitment, support, and leadership ▪ Lack of standard indicators and systems for data collection and performance assessment of CE in construction ▪ Limited circular designs for construction projects ▪ Lack of successful business models and frameworks to implement circular construction projects ▪ Complex planning requirements and management processes ▪ Lack of design tools and strategies for circular business models and circular products ▪ Lack of consideration for end-of-life issues of buildings
Regulatory barriers	▪ Lack of regulatory framework, appropriate policies, and sound legislations for CE in construction ▪ Lack of government financial support mechanisms and tax incentives for circular business models ▪ Lack of regulatory pressure and stringent regulations ▪ Lack of clearly defined national goals, targets, and visions for CE in construction ▪ Lack of sound infrastructure for CE in construction

	▪ Poor institutional support and framework for CE in construction ▪ Weak enforcement of rules and regulations for environmental protection ▪ Lack of incentive to design for end-of-life products ▪ Lack of industry support, standards, and technical guidelines for circular construction projects ▪ Obstructive laws and regulations (e.g., low taxes on landfill disposal) ▪ Lack of CE and environmental management certifications and accreditation systems ▪ Lack of promotion and large-scale demonstration projects ▪ Lack of environmental laws and regulations ▪ Unavailability of environmental management programs and facilities ▪ Lack of standard guidelines for remanufacturing and refurbishing products
Technological barriers	▪ Fragmentation and complexity of the CE supply chain network in construction ▪ Lack of a cohesive reverse logistics network and facilities ▪ Lack of appropriate supply chain partners ▪ Lack of integration and collaboration among supply chain partners in construction ▪ Limited circular procurement practices and strategies in construction ▪ Insufficient suppliers of circular materials and products ▪ Lack of complete supply chain network ▪ Lack of quality circular materials, products, and services ▪ Lack of green manufacturing processes and logistics in construction ▪ Lack of producer-based responsibility system in production of construction materials
Stakeholders barriers	▪ Poor cooperation, collaboration, and communication among stakeholders in CE value chain ▪ Lack of data transparency and information sharing among stakeholders ▪ Lack of appropriate partners and participative network ▪ Lack of trust among stakeholders ▪ Lack of support and involvement of stakeholders
Supply chain barriers	▪ Fragmentation and complexity of the CE supply chain network in construction ▪ Lack of a cohesive reverse logistics network and facilities ▪ Lack of appropriate supply chain partners ▪ Lack of integration and collaboration among supply chain partners in construction ▪ Limited circular procurement practices and strategies in construction ▪ Insufficient suppliers of circular materials and products ▪ Lack of complete supply chain network ▪ Lack of quality circular materials, products, and services ▪ Lack of green manufacturing processes and logistics in construction ▪ Lack of producer-based responsibility system in production of construction materials
Technical barriers	▪ Lack of technical and technological know-how to implement CE practices ▪ Technical complexity of transitioning from linear to CE in construction projects ▪ Scaling difficulty for CE in construction ▪ Insufficient technical resources and infrastructure (e.g., collection centres and recycling plants) for CE in construction ▪ Complexity of construction products and projects
Organizational barriers	▪ Increased organizational processes, planning, and burden ▪ Unsupportive business culture and organizational norms ▪ Excessive dominance of the traditional resource-intensive business models in construction ▪ Inadequate organizational resources and capabilities ▪ Complex administrative requirements and legal procedures ▪ Lack of strategic organizational planning and practices for CE

2.1.3 Barriers to biobased building

No research has ever been done on the barriers in the building sector building with biobased materials in the Netherlands. In Sweden, researchers investigated the drivers and barriers to the increased use of biobased building materials. The methods Theory of Planned Behaviour and Innovation Theories are used to research with a qualitative approach with semi-structured interviews with Swedish architects, contractors and developers (Markström, Bystedt, Fredriksson, & Sandberg, 2016). The research resulted in the table below.

Tabel 4 Framework barriers for building biobased in Sweden (Markström, Bystedt, Fredriksson, & Sandberg, 2016)

Categories	**Barriers**
Financial	▪ Developers think of purchase price and the cost of installation whereas the developers consider the life cycle cost where the need of maintenance is of importance.
Aesthetical	▪ The architects consider the need of maintenance as important, but from an aesthetical point of view
Risks	▪ High risk; further use is considered risky because of their reputation. The reputation is new, untested and less long lasting and too expensive. The listed risks are mold and moisture damage, difficulty in meeting fire regulations, and negative effects on human health and the environment from the chemicals needed for fire protection.

	▪ Uncertainties regarding the quality of a material. ▪ Developers are worried about an increased burden in maintenance and that the potential initial environmental gains with a biobased material will be lost if the service life proves to be short. ▪ Contractors see the risk of an extra cost and bad reputation if the material fails within the warranty period. ▪ Developers think it is important how the customer perceive the materials. ▪ Other important criterions are delivery time, supply security, and assembly period for the contractors.
Reputation	▪ Bad examples contributes to a conservative and reluctant attitude. Architects and constructors think of isolation systems and developers think of wood buildings.
Lack of knowledge	▪ There is also a lack of knowledge among building engineers and architects of which biobased alternatives that are available, and how and where to use them.
Small profits of contractors	▪ Small profit margins among contractors also contribute to the reluctance of using other materials than the commonly used and since there are plenty of building projects, they do not need to be that innovative in order to get work.
Lack of supply	▪ Another barrier is that biobased materials are marketed to a less extent than other materials.

The barriers focus on the transition to the CE of which biobased building is part. These barriers were not chosen as a framework because they do not give a complete picture as only developers, architects and contractors were interviewed and no other actors. From the ETH in Zurich (Switzerland), research was conducted in 2022 on the barriers and opportunities of the rapidly growing use of biobased materials in buildings. How this research was conducted is not described, only the results are shown. Two questions are examined namely: "Given the urgency of the climate crisis, what are economically (and environmentally) viable solutions for building materials?" and "What actions are needed to support this transition?". Research results are only advice and solutions but not barriers (Göswein, Arehart, Phan-Huy, Pomponi, & Habert, 2022). In Sweden is also research conducted about the perceptions of Swedish architects and contractors regarding the use of biobased building materials. The research is based in Sweden and will be extended to the European level. This is an interesting research because this study is intended to contribute to the understanding of the drivers and barriers to increased use of biobased materials. The research is conducted with a qualitative approach with semi-structured interviews (Markström, Bystedt, Fredriksson, & Sandberg, 2016).

2.1.4 Biobased building materials

This chapter presents further studies on the use of biobased building materials, which in their conclusion also present barriers or mention similar aspects. A study by Yadav and Agarwal (2021) about an overview of biobased building materials recommends that it is important to focus on the tools that have the potential to transform thoughts and ideas into meaningful actions to create a sustainable world. This indicates a lack of tools that can turn ideation into action. In addition, a new way of thinking is needed where standard constraints are left behind. The higher price of biobased materials needs to be communicated using reliable analyses to persuade traditional builders such as an improved LCA technique. This indicates a lack of reliable measurement tools and a new way of thinking. Research by Amziane and Sonebi (2016) on an overview of biobased building materials made with plant aggregate concludes that these materials have great potential in the market of building materials worldwide and further on its benefits. Also one in the conclusion is critical of the current position in the market namely in relative infancy in the material. This is because of the lack of research conducted on how best to use it and its natural low-carbon properties and mechanical capacity such as its ability to bear loads. Also lacking are figures for reducing a building's carbon footprint and improving insulation both thermally and acoustically. Research by Wilk (2022) on the directions and development prospects of the biobased building materials market concludes that the market is very diverse and could replace the market for conventional building materials. This requires adaptation by architects and designers in construction and during operation. At the end of the building's life, it still has value because biomaterials can be transformed or reused. Besides being environmentally neutral, biomaterials also have a positive effect on the environment and are therefore very important in times of climate crisis.

According to Wilk, it is therefore important to increase the availability of biobased building materials and make consumers aware of the possibilities in them. It is also necessary to redefine conventional building solutions. Research by Oostra and Sailer (2016) concludes that technological progress and competitiveness must be accelerated or biobased materials are unlikely to gain a serious market position compared to traditional products with more negative environmental impacts. Circular economy concepts as well as creative implementation strategies are also required to realise the ambitions.

In addition, many studies have been published on the relationship between biobased building materials and health and comfort. For example, research by De Visser, Van Wijk and Van der Voort (2015) focuses on health, comfort, energy use and sustainability issues related to the use of biobased building materials. Part of the conclusion is the constraints related to the use of biobased building materials. The first constraint mentioned is the lack of a complete national environment database of the Netherlands which is relevant for calculations measuring the effects of the use of the materials for certificates and subsidies. As a result, these materials may be too expensive, making a project unfeasible and leading to a choice of traditional materials. Secondly, the existing public tenders for building projects have too heavy an administrative burden, making it unfeasible for small companies active in the biobased building industry to participate. Thirdly, most contractors are not familiar with the technical properties and application of biobased building materials. Fourthly, the sustainability image of biobased building materials is not sufficiently promoted among consumers. Fifth, biobased materials are more expensive associated with their lower market volume and scale. Sixth, it is unknown how these materials will perform in 30-40 years (Visser, Wijk, & Voort, 2015).

2.2 Theoretical framework(s)

To answer the research question, it is helpful to have a theoretical framework as starting point. In this case, this framework is based on barriers. No study has investigated the current barriers to building with biobased materials in the Netherlands. This current theoretical framework is therefore based on several studies related to barriers in CE and biobased building in other countries. There is no whole framework which can adequately answer the entire main question. Therefore, a composite framework based on frameworks of barriers to the transition to a CE was chosen. Since biobased construction is part of a CE, these barriers seem relevant and useful for this research. Biobased building is part of a CE because the use of biobased building materials is about finishing and generating short loops (Material District, 2014). From this, it can be concluded that the barriers of biobased building should be part of the barriers to the circular economy. It is chosen not to include the barriers to biobased building in Sweden (2016) because it is only based on interviews of architects, developers and builders and this research is also to context. The framework below has been compiled as a basis with indicated sources from which the typologies come. This framework covers the entire context as much as possible so that all barriers can be identified during the study. The framework provides structure because the barriers found can be placed in the typologies. The framework does not create tunnel vision because the typologies selected are broad and a combination of the barriers found in the literature.

Table 5 Theoretical framework (author)

Typology	**Source**
Socio-cultural	(Wuni, 2022; Bilal, Khan, Thaheem, & Nasir, 2019; Charef, Morel, & Rakhshan, 2021)
Technical	(Wuni, 2022; Habold, 2020)
Economical	(Wuni, 2022; Bilal, Khan, Thaheem, & Nasir, 2019; Charef, Morel, & Rakhshan, 2021; Habold, 2020)
Institutional	(Wuni, 2022; Habold, 2020; Bilal, Khan, Thaheem, & Nasir, 2019)

2.3 Operationalisation of theoretical concepts

This subheading operationalises the abstract variables. The result is the conceptual model, which is represented at the end of the chapter.

2.3.1 Biobased materials for construction

The term 'biobased' is used for materials where the origin and means are made of renewable raw materials and completely or partly consist of biological materials. The term 'renewable' means that the raw materials can be quickly recreated naturally (generally within 10 years) (Quist, 2021). These materials can sequestrate carbon emissions (Heidari, Mathis, Blanchet, & Amor, 2019). Biobased materials have the quality that they can have negative emissions by storing and retaining emissions during growth (Jiang, Lawrence, Zhang, & Cui, 2020). Several studies show that using biobased materials is a better option for the environment than using traditional building materials such as concrete (Krasny, Klaric, & Korjenic, 2017; Pacheco-Torgal, Ivanov, & Tsang, 2020). People have been using environmentally damaging and exhaustible materials such as concrete and steel in the construction industry for many years (Pacheco-Torgal, Ivanov, & Tsang, 2020). Also, the use of biobased materials in the construction industry would reduce climate-related problems such as global warming on a global scale. Preserving the climate by reducing greenhouse gases is one of the main drivers of this (Sofiane Amziane, 2016). According to Sofiane Amziane (2016), the use of conventional building materials affects four important aspects of the environment, namely greenhouse gas emissions, energy consumption, consumption of natural resources and, consequently, huge waste production. Also, the replacement of plant-based materials has a positive impact on health and ecology. According to Material District (2014), there are two main categories of biobased materials; conventional and emerging materials. Conventional materials are biodegradable and come from animals or plants for example pulp, bamboo, coconut fibres, paper, wood and leather. Emerging materials/bio renewables are active subjects of research and development for example sugar beets and polylactic acid (PLA) for use in plastics. According to Bader's research (2021), in this transition the knowledge exchange among the actors of the innovation system appears limited, causing uncertainties for both supply and demand. The knowledge gained is not translated into a strategy and educational programs are very limitedly focused on biobased building. Current policies for the Dutch building sector do not encourage biobased building because of the lack of a shared vision. In addition, financial resources limit further investments by entrepreneurs because the niche market leads to higher prices compared to conventional materials.

2.3.2 Barriers

Extensive research on barriers to the development and implementation of climate change adaptation strategies is available on this subject. Understanding the nature of barriers is important for adaptation to address them strategically. Research in 2013 shows that the current academic literature is fragmented in this area. There is hardly any definition of barriers and no clear indicators to systematically identify and assess them. There appears to be a huge list of barriers which is endless. Most of the barriers studied are institutional and social. Barriers are identified as non-climatic factors and conditions arising from the actor, governance system or system of concern. These studies are mainly done in developed countries with a focus on water-related domains. Most of the studies are inductive case studies while comparative contexts are limited. Most studies make interventions to overcome barriers. Therefore, this study recommends that the questions "if" and "what" barriers are left out and start with the questions "how" and "why" barriers arise (Biesbroek, Klostermann, Termeer, & Kabat, 2013).

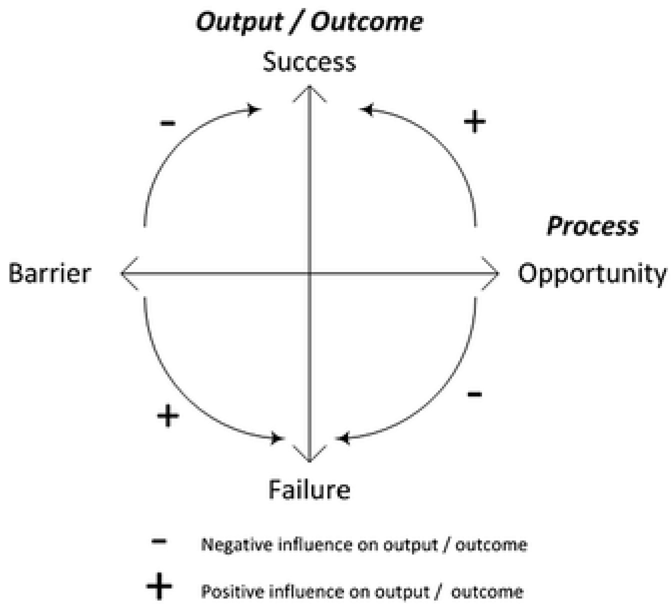

Figure 8 'Barriers' on the continuum of process and output/ outcome (Biesbroek, Klostermann, Termeer, & Kabat, 2013)

In Figure 8 the concept of barriers is seen as part of a governance process that influences output. In this way, the focus is not only on which barriers influence the outcome but also on what causes these barriers. In this way, it can also be shown whether the barriers may be the reason for the failure of the transition to biobased building materials or whether this is due to a lack of opportunities.

2.3.3 Types of barriers

The barriers are categorised into four typologies; sociological/cultural, technological and economical and institutional barriers. No research has been done on these barriers in biobased building so therefore these concepts are defined and explained using the CE.

Socio-cultural barriers

Sociology is defined as the science of society (Van Dale, 2023). In terms of barriers, the focus is on knowledge, culture and stakeholder barriers. According to Charef et al (2021), sociological barriers include aspects such as people's behaviour and awareness of climate impact. Cultural beliefs and the reputation of the material also play a role. These aspects influence consumer choice behaviour. These barriers include according to Wuni (2022) in the circular economy the lack of transparency and sharing of information. Businesses and policymakers are cultural barriers the main barriers to a CE driven by market barriers. These are introduced by a lack of governmental interventions. For example, limited circular requests appear to be made and obstruct laws and regulations.

Technical barriers

The technical and technological barriers, according to Wuni (2022) and Charef et al (2021), include the lack of know-how to implement CE, the technical complexity of the transition to circular construction and scaling up CE materials. Charef et al (2021) add data-related barriers and product quality.

Economical barriers

The economic barriers are focused on the market and the financial barriers. Part of the market is also the supply chain. According to Wuni (2022), there is a lack of market pressure and competition in terms of circularity, also the market of circular products is very uncertain. Because the market is quite limited, there is also a lack of the limit of circular products. There is therefore a lack of a chain of supply chain partners and it is mentioned that this is fragmented and complex. There is also a lack of circular construction procurement.

Institutional barriers

Path dependency is central to institutional barriers, developments in organisations and institutions almost always originated or/and influenced by path dependency (Schreyögg, 2010). Institutional barriers are deep-rooted: industry policy is still based on a linear economy (Gumley, 2014). The implementation of CE relies on governmental actors. Also, part of this typology is regulatory barriers. According to Charef et al (2021), there is a lack of policy regulations and they lack an approach because it is too complex because it is new. For instance, a circular construction standard is missing. Support is also lacking and the application regulation is slow. Wuni (2022) adds that a regulatory framework is missing for CE construction, there is also a lack of financial support mechanisms from the government such as grants. All this starts with the lack of national goals, targets and visions. A major barrier is that the current knowledge and regulatory system is not set up for a CE.

2.3.4 Process and actors in building biobased

The figure below from Bader's research (2021) shows the innovation system actors of the Dutch construction sector based on the Agenda City report (Agenda Stad, 2021). Scaling up depends on the actors in the "Demand" category. In this category, a distinction can be made between private and public actors where private is between citizens and citizens or businesses such as investors, and construction companies and the public is between citizens and government. Public actors are governments and housing corporations. They can play an important role in the transition to building with biobased materials by applying these materials in their building projects (Michielsen, Groot, & Veenstra, 2019).

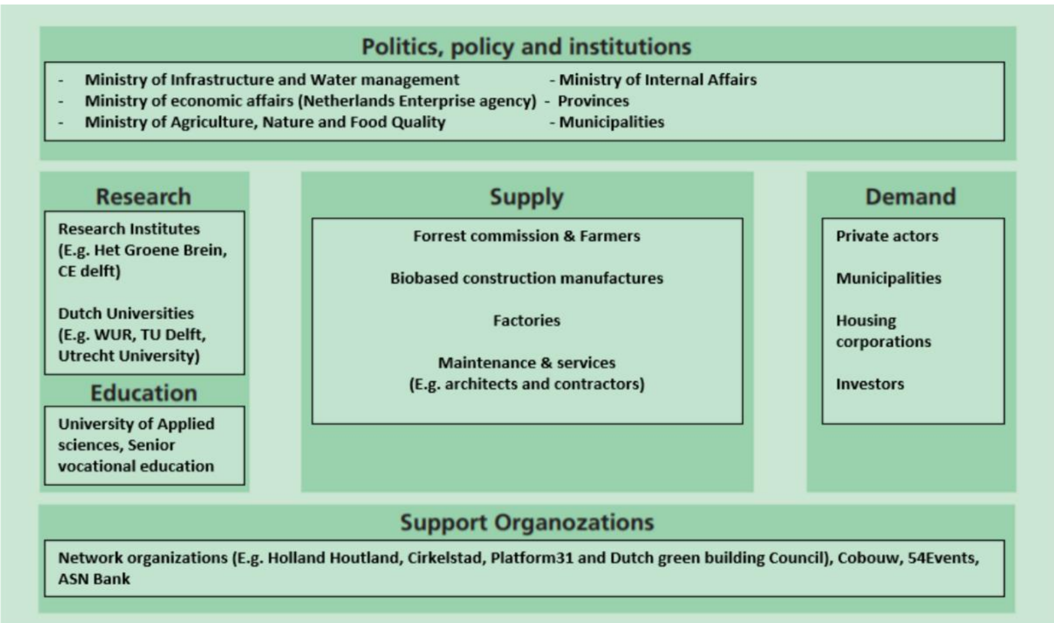

Figure 9 The innovation system of biobased construction materials in the Dutch construction sector (Bader, 2021)

2.3.5 *The conceptual framework*

The conceptual framework is shown in Figure 10. Two factors are shown: 'The use of biobased building materials' and 'Barriers'. The barriers influence the amount of biobased materials used. The use can also influence the barriers because if, for example, many biobased building materials are used, then the barriers can become less. For example, more confidence is gained in the product. What these barriers are is the research question and this is examined using the four typologies; sociological/cultural, technical, economic and institutional.

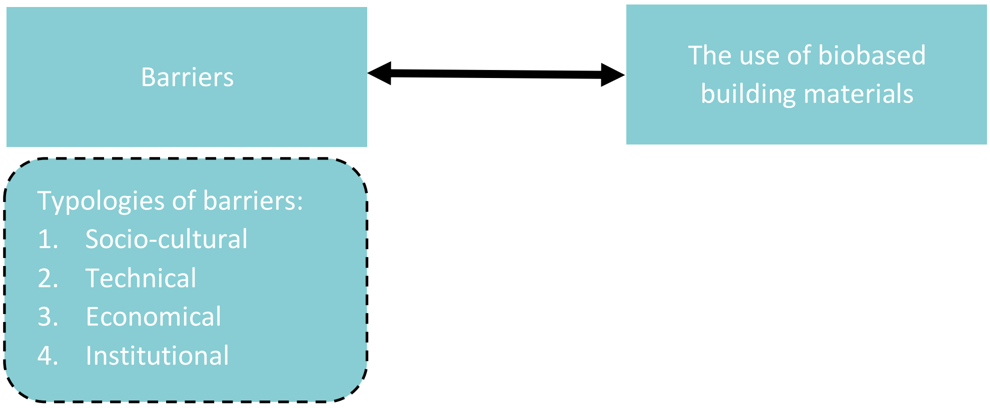

Figure 10 Conceptual framework (author)

3 Methodology

This chapter deals with the methodology of the study. In it, the strategy of the study is discussed. Research methods are linked to this strategy and how the data is analysed. The chapter closes with the validity and reliability of the study.

3.1 Research strategy

Barriers to biobased construction in the Netherlands have never been researched, and according to Van Thiel (2014), exploratory research is then an appropriate strategy. This can also be seen from the research question because the question is open-ended and starts with 'what'. According to Van Thiel (2014), the exploratory type is inductive research as there is little knowledge about the subject and it has never been researched before. Inductive research is shown in the figure below on the right side of Figure 11 (blue arrow). A problem has been identified with the current emissions of carbon emissions and the use of exhaustible materials in the building sector cause climate problems this can be solved with the use of biobased building materials but there appear to be barriers in applying this and these barriers are being investigated. This corresponds to the inductive side of the cycle (Van Thiel, 2014).

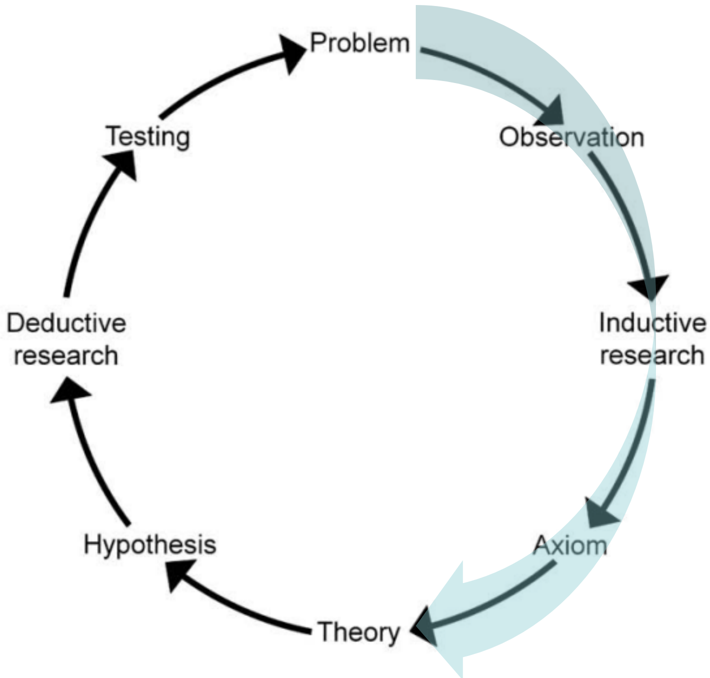

Figure 11 Schematic outline of empirical cycle (Van Thiel, 2014) edited by author

A qualitative research methodology was chosen for this study due to its suitability for exploring the barriers. This cannot be done with quantitative research methodology because it cannot be captured in numbers. By applying qualitative research, barriers can be clearly defined and depth can be achieved by not being limited by numbers. Another advantage is that the questions can be sharpened during the study when, for example, new data is available or can be responded to what is going on. Qualitative research is also suitable for researching multiple causalities (Symon & Cassell, 2012), such as several barriers. Qualitative research is preferred in research about people, events and situations which are characterised by more variables than anyone can identify (Perskin, 1993). According to this theory, qualitative research is very suitable for this research because many different actors experience barriers and events are decision moments that determine the choice of building materials, the situations are building with biobased or traditional building materials, which are preceded by certain choices.

3.2 Research methods

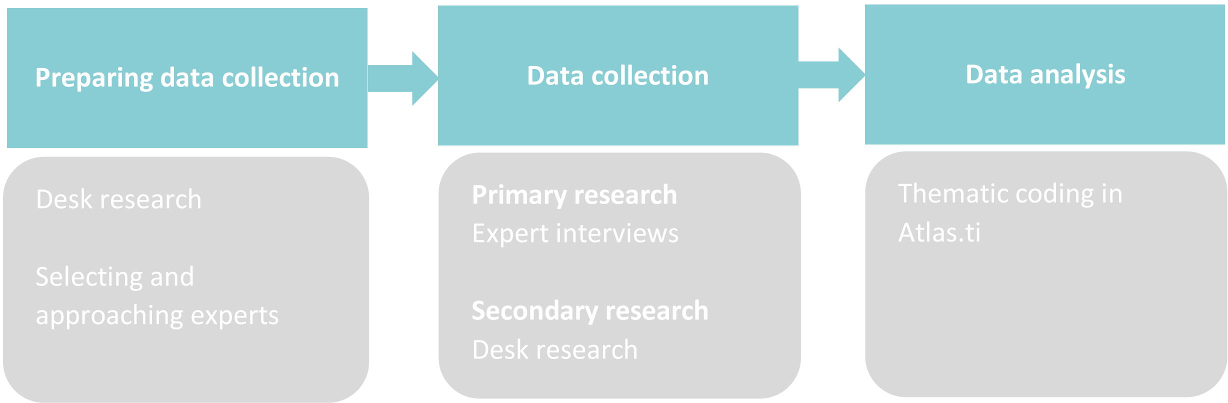

Figure 12 Research process

To identify barriers, the process above will be followed consisting of preparing data collection, data collection and data analysis. Research is conducted on barriers in the Netherlands and therefore it was chosen to interview representatives of the actor groups. Respondents are determined based on the "The innovation system of biobased construction materials in the Dutch construction sector", (Figure 9) by Bader (2021). This model will be validated by experts and desk research. This is also important in preparation for the interviews so that the researcher gets an overview of the market for building homes with biobased building materials.

3.3 Data collection

This heading shows the data collection. These consist of interviews as primary research and desk research as secondary research. How this was carried out and what choices were made is explained in this heading.

3.3.1 Selection interviewees

To determine who will be interviewed to research barriers to the use of biobased building materials, the biobased building chain and the literature about actors in the chain were taken as a starting point. There is a lot of discussion about the chain of biobased construction but not what it looks like. Using desk research to search for information on what the chain looks like and the results and, based on these, one process was created as a basis for determining the interviewees. Figure 13 shows a chain of biobased building developed by Van de Groep (2022), an expert biobased building, based on an LCA (Figure 14). Also, a report by Arcadis (2022) uses a similar chain which consists of the following phases:

1. Origin/source
2. Production
3. Application and use
4. End Life Cycle

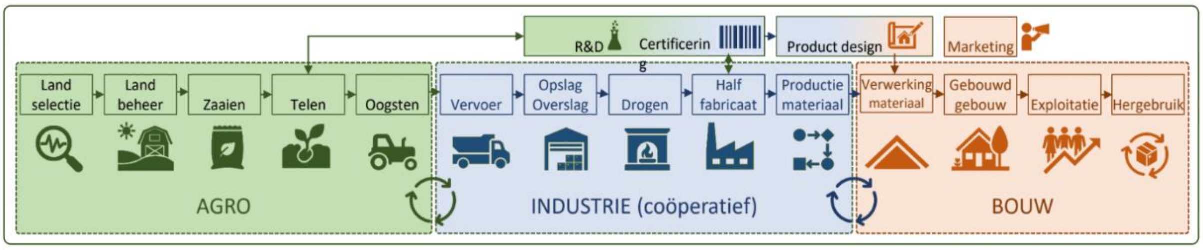

Figure 13 Chain biobased building (Groep, 2022)

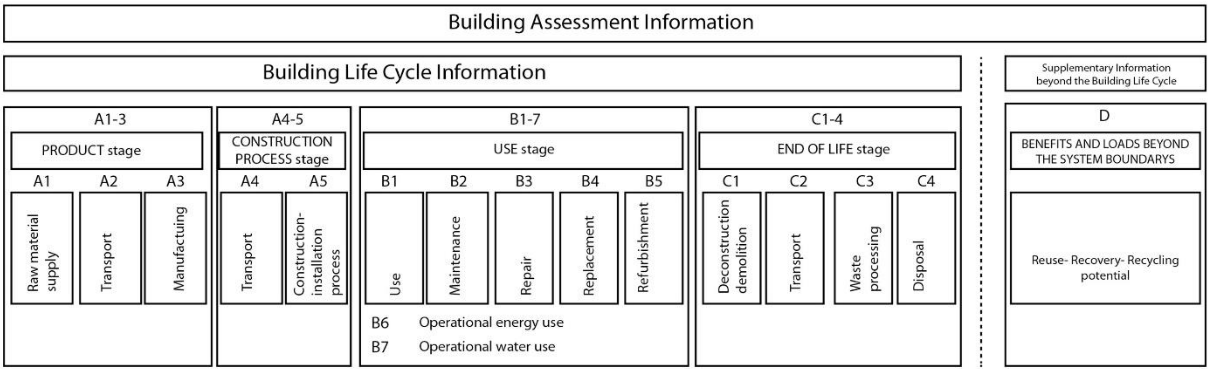

Figure 14 Building Assessment Modules for LCA (Vilches, Garcia-Martinez, & Sanchez-Montanes, 2017)

The above process (Figure 14) is the Life Cycle Assessment (LCA) of biobased building materials. This is a method of assessing the environmental impact of products, looking at the entire life cycle of the product (Rijksinstituut voor Volksgezondheid en Milieu, 2011). An LCA was chosen as an overview of the process because it is the only scientifically based process of biobased building materials. The chains found from desk research and literature research led to the following categories shown in Figure 15:

1. Experts on the whole process
2. Production of raw materials
3. Industry
4. Building

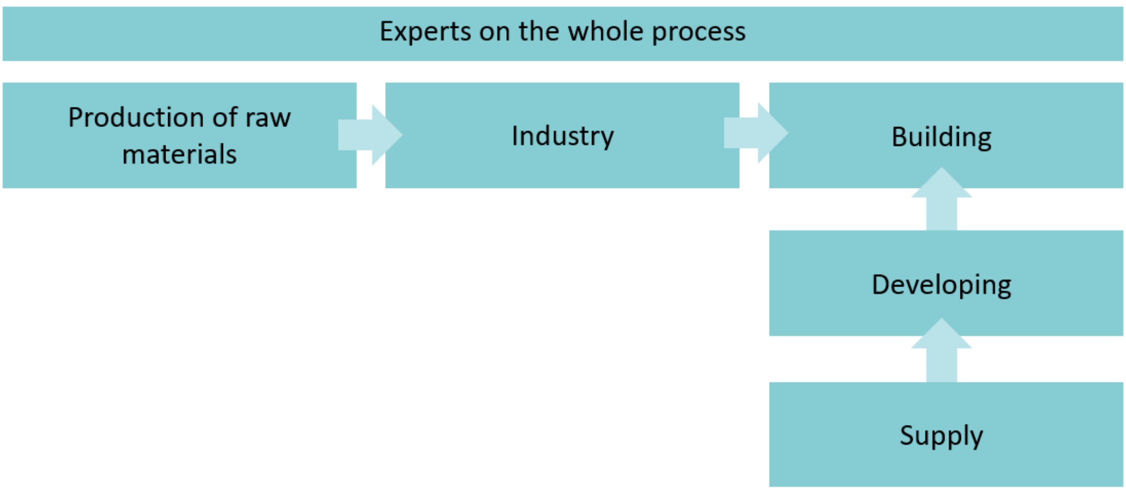

Figure 15 Process based on the chain (author)

To determine the actors in the chain desk research is done. Bader's innovation system of biobased building materials shown in Figure 17 was also included in completing the process. This system is based on the Agenda City report (Agenda Stad, 2021). The actors who use this system are the ones who take over the demand for biobased products such as housing corporations, investors and municipalities. These parties can play an important role in the transition to building with biobased materials by applying these materials in their building projects (Michielsen, Groot, & Veenstra, 2019). An overview of actors in biobased building by CE Delft (2021) also shows the demand side for biobased housing. For this reason, the demand side is added to the process of determining the actors in the chain for the interviews. This resulted in the final chain where the actors are added shown in Figure 18.

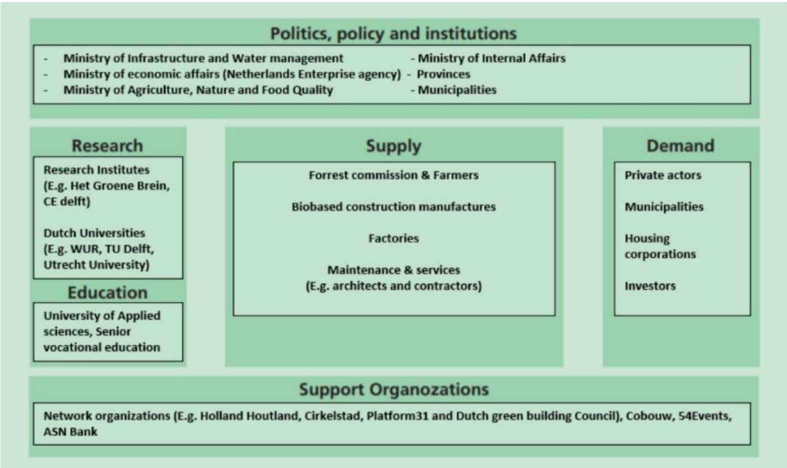

Figure 17 The innovation system of biobased construction materials in the Dutch construction sector (Bader, 2021)

Figure 16 Actors in biobased building (CE Delft, 2021)

3.3.2 The interviews

In Table 6, the list of interviewees is shown. It was chosen to interview only frontrunners given time constraints. Leaders were chosen because they see the barriers and know them so that depth can be achieved in the results. People who are opposed are expected to come up with more general barriers since they probably have not tried it and the frontrunners have. Therefore, the frontrunners are better placed to know what the barriers are. The purpose of the interviews is to answer the main and sub-questions and these are captured in the typologies. Therefore, selecting the interviewees also takes into account capturing enough data on the typologies. This paragraph addresses the expectations they capture with these actors. The economic typology is expected to be an important aspect and offered in all interviews. Especially in the interviews with supply, building, industry and production, it will be on offer as they deal with it directly. The technological typology will be a particularly influential aspect in industry and building. The political and institutional typology is expected to come into play with all actors as they all experience the impact of government influence and path dependency. The social and cultural typology will also be experienced by all parties as this is new for everyone and to a transition all actors react in their own way.

Table 6 List of interviewees and information

Nr.	Interviewees name	Organisation	Description of interviewees role	Date interview
1	Jip van Grinsven	Alba Concepts	Consultant	04/04/23
2	Jeroen Prinsen	Barli	Plan developer	04/04/23
3	Merlissa Diele	Natuurverdubbelaars	Environmental economist	05/04/23
4	Dirk Bugter	Triodosbank	Mortgage advisor	06/04/23
5	Rosa Bos	Ballast Nedam	Developer	11/04/23
6	Sandra Nap	Holland Houtland	Director	12/04/23
7	Emma Lucassen	AM	Developer	13/04/23
8	Norbert Schotte	Gideon	Transition maker	14/04/23
9	Rolf Gerritsen	Province Noord-Brabant	Circular building project manager	17/04/23
10	Mark Compeer	Nice Developers	Developer	18/04/23
11	Johan Paul Borremans	Derix	Director of the Netherlands office	19/04/23
12	Pascal van Dam	Province Zuid-Holland	Transition officer team circular	21/04/23

Below in Figure 18, the organisation related to the interviewees are shown in the biobased chain to show that the entire chain was included in the study. In Figure 19 Characteristics of intervieweesFigure 19 and Figure 20, the interviewee's statistics are shown. This shows that the group of respondents is sufficiently mixed in terms of gender, education level, employee vs employer and age.

The interviews were conducted using one interview guide which is shown I appendix A (Dutch) and B (English). This was chosen to enhance reliability. Semi-structured interviews were chosen because this is an appropriate method of data collection according to Van Thiel (2014) when little literature is available on the subject and the research is inductive. Also, the ability to ask further questions can provide additional depth. The interviews were conducted in Dutch because this is the native language of the researcher and the interviewees. This was chosen to allow the interviewees to tell everything as much as possible without language being a barrier. The interviews were held in the spring of 2023.

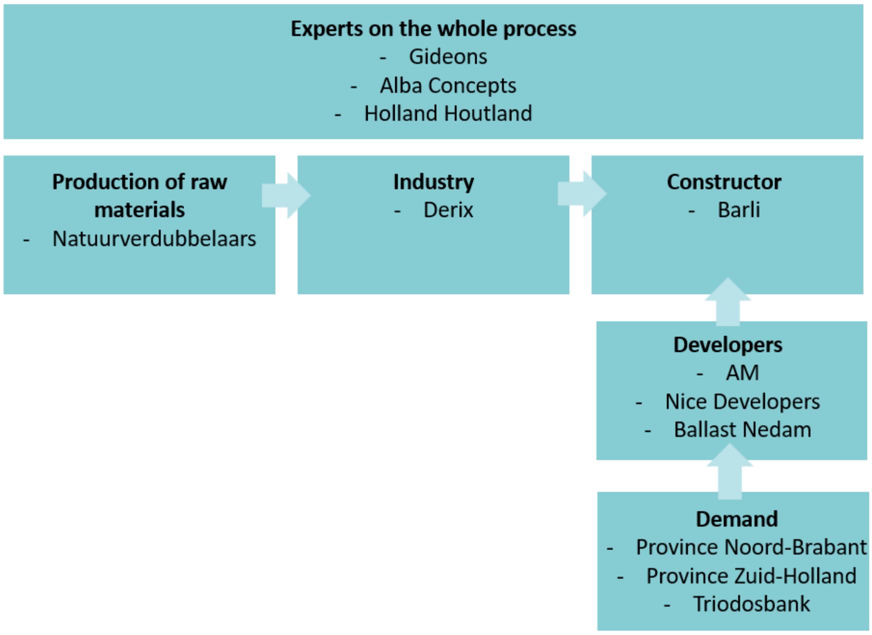

Figure 18 Chain with actors (author)

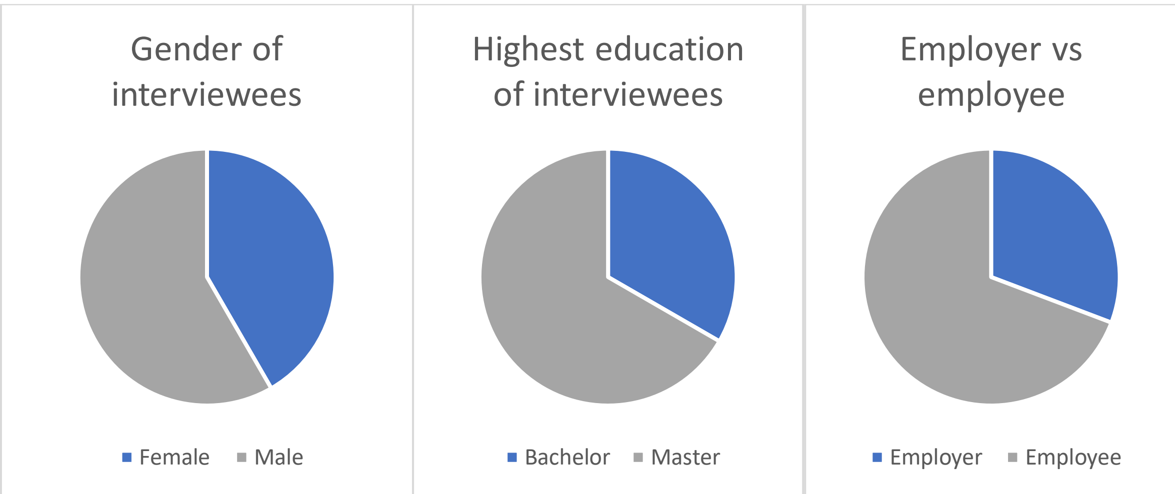

Figure 19 Characteristics of interviewees

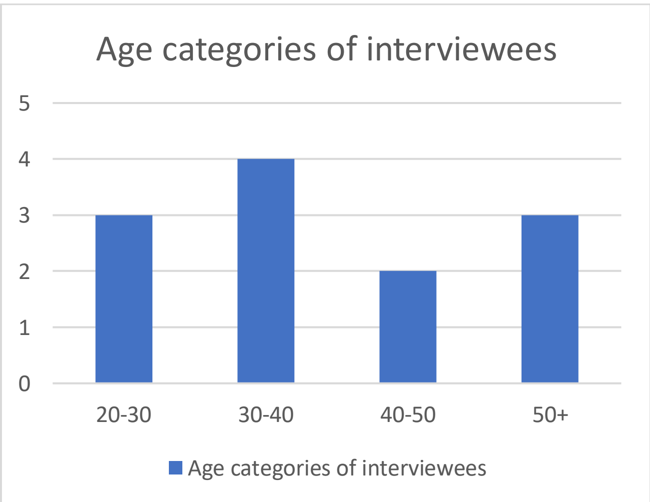

Figure 20 Age categories of interviewees

3.3.3 *Documents*

In Table 7 are the documents analysed. These documents were taken from the interviewees for in-depth analysis.

Table 7 Documents

	Document name	Year	Author
1.	Biobased: een pijler van de circulaire economie (translation: Biobased: a pillar of the circular economy)	2020	NIBE B.V.
2.	Kennisnotitie Biobased bouwen (translation: Knowledge note: Biobased building)	2021	Provincie Zuid-Holland; CE Delft
3.	De urgente belofte van biobased bouwen (translation: The urgent promise of biobased building)	2022	Arcadis
4.	Biobased Bouwen (translation: Biobased Building)	2021	Holland Houtland

3.4 Data analysis

After conducting the interviews, the result is a short note and a recording. This recording is transcribed at a certain level, this is determined by the purpose of the transcription. The other part of the data consists of documents resulting from the interviews. The purpose of the data is to find out the barriers experienced by the participants. For this reason, an edited transcription is chosen. This way, time is also saved and this benefits the research because more data can be collected this way. The data is analysed with the approach of content analysis using thematic analyses. It is important to first structure the data and delineate the boundaries between different information units, Van Thiel (2014) said, this is done with coding. The collected data is analysed using ATLAS.ti because it appears to have advantages, according to Van Thiel (2014). For instance, this way a lot of data can be processed systematically and the programme has several functions for retrieving and analysing the data which can never be done with the human brain. It is also easier to add information later. Deductive research codes use codes from the theoretical framework and inductive research creates codes when reviewing the data (Mihas & Odum Institute, 2019). The twelve transcripts and four papers are coded with an inductive approach. This was a creative process involving trial and error and logical thinking without hard-set rules as Robson and McCartan (2016) point out. The data was coded and themes were created from it. Based on these themes, the data was coded again (Saldana, 2015). According to Saldana (2015), there are different types of codes: interpretative codes, thematic codes and descriptive codes. The analysis of interviews is about content therefore descriptive coding was not chosen. Nor is it about interpretation which is why thematic coding was chosen. This involves looking for coherent constructs in the data and finding links to the research topic. This was followed by axial coding, where patterns were discovered from the codes and where categories were created using groups in Atlas.ti (Van Thiel, 2014).

3.5 Validity and reliability

The validity of research means the ability to research what needs to be researched to answer the research question (Goodwin, 2009). The research is exploratory and a drawback of this is that this type of research is often not externally valid and generalisable. Also, the results may be biased due to the lack of current knowledge about biobased buildings. There has never been researched into the barriers to biobased building, and according to Van Thiel (2014), exploratory research is then an appropriate strategy. The validity of the study is difficult because it is exploratory and qualitative (Becker, 1996). Exploratory research is to improve the validity of results of the further confirmatory phases of research (Zait & Bertea, 2013). Semi-structured interviews of the right representatives allow for a complete picture of the barriers to biobased building for those actors. However, a requirement is that the representative knows his actor group well and is aware of the developments at play. The form of semi-structured interviews allows the interviewee to name all barriers. Depth can also be requested where necessary. They can also be directed to get a complete picture and information on other parts of the study. To ensure validity, there must be enough participants so that they are representative of the whole group. According to Van Thiel (2014), in qualitative research, verifiability and repeatability are less straightforward than in quantitative research because most of the research takes place in the researcher's mind. For this reason, terms such as the understandability of the analysis, its transferability and the plausibility of the conclusions drawn are used.

According to Van Thiel (2014) consists reliability of the accuracy and consistency with which variables are measured. Accuracy is ensured by recording and transcribing the interviews; accurate coding is also done. Respondents must be critically selected so that they give a realistic picture of the group they account for. Consistency means that if the study is conducted again under similar circumstances, the results will be the same and this is difficult to assess in exploratory research. However, this can be achieved by interviewing enough respondents to get as complete a picture as possible. Conducting all interviews using the same interview guide and coding everything, in the same way, created accuracy and consistency in conducting the study. Extensive preliminary research was conducted to select the respondents. For substantiation, a scientific method namely LCA is used as a basis. About equal numbers of men and women of equally distributed ages are interviewed.

4 Results

In this chapter, the findings of an analysis of the interviews and documents are represented. The interviews were coded and several main themes emerged. Below is a summary of the interviews and how they are referred to in the text.

Table 8 Overview of data collection

Nr.	Document name	Organisation	Description of interviewees role	Designation
1		Alba Concepts	Consultant	Respondent 1
2		Barli	Plan developer	Respondent 2
3		De Natuurverdubbelaars	Environmental economist	Respondent 3
4		Triodos Bank	Mortgage advisor	Respondent 4
5		Ballast Nedam	Developer	Respondent 5
6		Holland Houtland	Director	Respondent 6
7		AM	Developer	Respondent 7
8		Gideons	Transition maker	Respondent 8
9		Province Noord-Brabant	Circular building project manager	Respondent 9
10		Nice Developers	Developer	Respondent 10
11		Derix	Director of the Netherlands office	Respondent 11
12		Province Zuid-Holland	Transition officer team circular	Respondent 12
13	Biobased: een pijler van de circulaire economie (translation: Biobased: a pillar of the circular economy)			D1
14	Kennisnotitie Biobased bouwen (translation: Knowledge note: Biobased building)			D2
15	De urgente belofte van biobased bouwen (translation: The urgent promise of biobased building)			D3
16	Biobased Bouwen (translation: Biobased Building)			D4

The first interview question was to name barriers in biobased building without going into detail. The results are shown in the table below.

Table 9 Overview first question interviews (biggest factors)

Resp.	Answer
1.	Affordability, myths, unfamiliarity
2.	Affordability, new applications, supply chain, certification
3.	Risks in the chain, physical distance, business case farmer, unfamiliarity
4.	Lack of circular/ biobased vision, guts of the government
5.	Lack of knowledge, building sector traditional, lack of need resulting in lack of demand
6.	Mindset, pilots, less doing and very consultancy-ish
7.	Affordability, risk-averse people in the building sector, MPG, different specs of biobased building materials
8.	Regulation

9. Unfamiliarity, lack of supply and lack of experience
10. Certification, innovation is a risk so a no-go
11. Fire safety in higher buildings for timber construction, biobased market less mature than traditional, internal noise protection
12. Regulation, a low MPG is not requested and carbon storage is not in it and a niche market with a lack of infrastructure

4.1 Product specifications and certification

According to multiple respondents, internal noise protection in wood construction is a major barrier. In the Netherlands, according to multiple respondents, we are used to relatively good acoustics in homes therefore acoustics are seen as a barrier in biobased homes (resp. 1, 5 and 11). According to other multiple respondents, biobased building materials have different specifications from traditional building materials, which affects workability and requires a different application. For example, biobased insulation material is thicker than traditional insulation material which requires different detailing (resp. 2, 7, and 9). Multiple respondents mentioned fire safety as a barrier. For instance, fire safety requires the use of traditional building materials in some cases (resp. 1, 2, and 11). A respondent indicates that fire safety is a major barrier in wooden multi-storey housing projects (resp. 11). According to another respondent, there is a lack of knowledge of fire safety (resp. 1). One of the respondents indicates that for some applications there is not yet a good, biobased alternative (resp. 7). Another respondent also mentions unfamiliarity with maintenance as a barrier (resp. 5). According to multiple respondents, there are no/nearly no technical barriers. According to them, this requires a different way of designing (resp. 6 and 8). They call this a social barrier rather than a technical or technological barrier. A respondent also indicates that the technical barriers can be solved but that this costs money (resp. 5). Multiple respondents also indicate that the traditional way of designing is a barrier (resp. 8 and D1). According to multiple respondents, there is a lack of knowledge of biobased building materials which is a barrier (resp. 5, 11, D1, D2, and D3). There is also little research into new biobased insulation materials. Research on biobased materials lags behind that of traditional materials and knowledge is fragmented (resp. D2).

In nine of the twelve interviews, certification was mentioned as a barrier, just not by a few respondents (resp. 4, 6, 7, D1, and D3). According to a respondent, building materials in the Netherlands need certificates to comply with the building code and to provide guarantees such as the completion guarantee. Developers want to take as little risk as possible and therefore choose certified products within the building code (resp. 5). According to another respondent, biobased pioneers cannot prove viability and their products are good for insurers and guarantee funds due to lack of experience (resp. 4). It is also difficult to get certificates because of cost, duration and facilities according to multiple respondents (resp. 1, 2, 5, 8, 9, 12, and D1). Respondents also indicate that the products are often still under development so then it makes more sense to apply for the certificate when the product is further developed (resp. 2 and 8). Another barrier to certification mentioned by respondents is the requirements for the certificates (resp. 9 and 10). This is because they focus on traditional building materials. In this, the traditional lobby has an interest in tightening the requirements on their own products as it is then more difficult for the biobased building materials to get the certificates (resp. 5 and 9). According to one of the respondents and a document, there are no warranty and insurance systems for biobased buildings yet (resp. 12 and D1). As long as these products cannot be insured, this is a major barrier. Figure 21 is an overview of the above results.

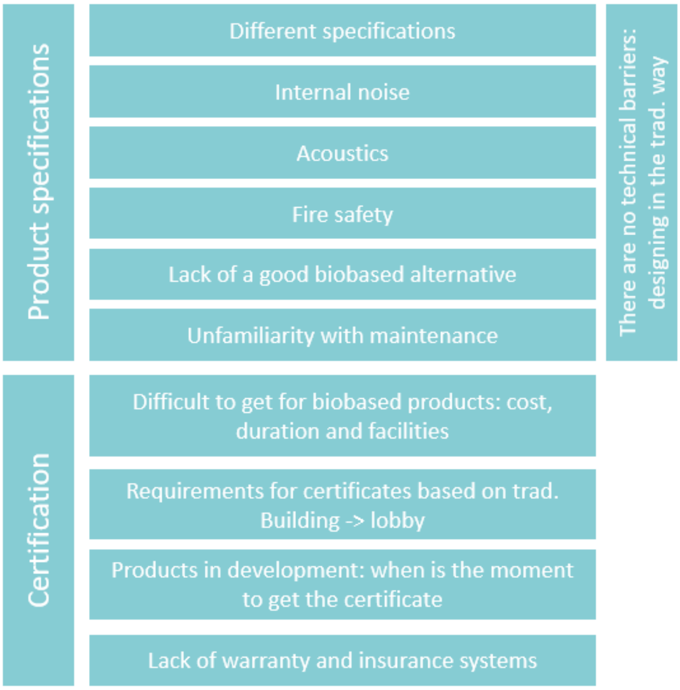

Figure 21 Overview 'Product specifications and certification'

4.2 Biobased chain and affordability

According to seven respondents, biobased building materials tend to be more expensive than traditional building materials, which is a barrier (resp. 1, 2, 7, 10, 12, D1, and D2). The competitor of biobased construction is traditional building which in many cases is cheaper, such as concrete (resp. 1, 2, 3, 5, 11, and 12). This is because traditional building methods are highly efficient due to their long-standing use. After all, it has been built this way for a long time and it has a huge scale compared to biobased building (resp. 1, 8, and D1). The biobased building market is a niche market with a lack of infrastructure and organisation (resp. 12). There are also learning costs and extra risks in biobased building materials that are no longer present in traditional building materials (resp. 7 and D1). The biobased market needs time to develop (resp. 2). Basically, traditional construction is very cheap (resp. 1 and D2) and brings disadvantages that are not paid for. The social benefits of biobased construction such as health benefits and carbon capture are not deducted from the price of biobased products.

Later in this theme, the different problems that parties in the chain encounter are listed by party. There are several barriers in general, these are mentioned first. The first barrier mentioned by multiple respondents is that parties in the biobased chain point at each other, such as the 'chicken-and-egg story' (resp. 2, 3, and 12). For instance, farmers say they are held back by a lack of buyers. While the producers, the farmers' customers, say they are not starting because of a lack of supply of biobased crops. In this way, parties point to each other to take the first step, according to a respondent (resp. 6), resulting in nobody taking the first step because of dependence on each other according to another respondent (resp. 1). Another factor is that there is a lot of ignorance in the chain about the availability of materials and other information. The chain knowledge is also called asymmetric because the information is there but not in the right place, so buyers do not know what the supply is but the supplying and producing parties do according to one of the respondents (D1). According to multiple respondents, parties in the chain are waiting for regulations from the government (resp. 12, D1, and D3). Another barrier is the lack of organisation and good infrastructure in the chain because the chain is very fragmented and the biobased market is a niche market. A market that is less mature than the traditional market (resp. 5, 11, and D1) and cooperation is lacking in the chain (resp. 1 and D2).

According to another respondent, organisations try to reinvent the wheel themselves (resp. 6). The chain also consists largely of start-ups which need time to get everything right (resp. 2). In the chain, according to another respondent, the focus is also often on what cannot be done: 'an incomplete chain therefore impossible' (resp. 6). If everyone keeps going for the cheapest (traditional) then this will remain the cheapest (resp. 7).

Farmers
According to multiple respondents, farmers will transform only when growing biobased products has a viable business case (resp. 1, 3, and 12). Currently, the returns of traditional crops are higher than those of growing building materials (resp. 3 and 12). There are also the risks of crop failure and no sales. A farmer starts this when he is assured of good sales. Also, some crops require high investment costs, creating an additional barrier such as cattail. The physical distance between farmer and producer is a barrier for certain products (resp. 3). For instance, for cattail it is important to process it as locally as possible, whereas wood can easily be shipped to the Netherlands from, say, Scandinavia because it is bulk. This aspect also affects the feasibility of the business case. Although importing biobased building materials is seen as bad for the environment (D3).

Producers
The risk of crop failure resulting in no supply of biobased materials is also a barrier among producers according to multiple respondents, respectively (resp. 2 and 3). In addition, there is a lack of processing parties and plants according to other respondents (resp. 3 and 8). Besides the uncertainty of supply, the risk of sales is also a barrier (resp. 3). A manufacturing company will not grow without certainty of sales (resp. 2). Biobased producers focus on their products and not on the holistic perspective (resp. D1). There is also a lack of structural engineers who can calculate wooden structures (resp. 11). It is difficult for start-ups to compete with the current market due to a lack of capital and expertise (resp. 9, D1, and D2). To get started, one has to make a hefty investment (resp. 1). According to one of the documents, standardisation and an off-take guarantee require constant quality, delivery and off-take guarantees and logistics (D2). This is difficult for construction products from agricultural and natural waste streams. Another aspect at play is the 'Valley of Death', see the heading subsidies.

Developing and building
According to multiple respondents, a barrier is an uncertainty in the supply of biobased building materials. For instance, good biobased insulation appears to be little available and expensive (resp. 2 and 9). Multiple respondents mention the lack of experience in building with biobased materials (resp. 9, 11, D2, and D3), while another respondent indicates that the supplier provides explanations for the application of new products on the building site (resp. 2). A contractor does not often suggest biobased construction because of a need for comfort. The current low-profit margins of builders are also a barrier as this avoids risks (resp. D1 and D2). According to a respondent, there is a lack of a good biobased alternative to some materials (resp. 7). This should come from the architect's or client's demand (resp. 11). There is also a lack of knowledge among buyers about the biobased supply (resp. D1 and D3). As a result, there is uncertainty in biobased materials, leading to additional costs of proof and building is done on the safe side which also leads to higher costs. Another barrier is the existing network, and the relationships in the construction industry (resp. 7, D1, and D2). People work with standard relationships to ensure guaranteed material flows. The other side of this is that one already has a chain and can transform together into a biobased chain (resp. 7).

According to a respondent, there is a lack of knowledge in calculating timber structures among contractors and construction companies (resp. 11). In specific, calculating the details proves to be a barrier as projects become increasingly complex. The complexity is increasing at an enormous speed, with the pitfall being that the knowledge is not keeping up. There is already a shortage of carpenters, draftsmen and structural engineers and the demand for these will only grow. Another respondent also indicates that there is a shortage of experience in working with biobased building materials (resp. 9).

Demand

Private individuals, investors, social housing corporations

According to one of the respondents, there is high demand for biobased housing from private individuals (resp. 10). Individuals are lowering their housing requirements because of the housing shortage and since housing is a basic need (resp. 9). Therefore, the demand from the market for biobased housing from private individuals is not increased. Only private individuals who have the money to build their own homes. A bank influences this (resp. 4), for example, banks can give interest rate discounts on mortgages on biobased houses as has been done with energy labels. But the guts are lacking in other banks (resp. 4).

According to one of the respondents, there is a lack of sustainability goals among pension funds, which is why the demand for biobased homes is not picking up (resp. 8). While another respondent says investors like adding biobased homes to their portfolio (resp. 10). After all, pension funds get points when they invest in green housing and see a future in biobased construction. Among investors, barriers arise in heads such as filling in that it is more expensive without calculating or thinking that there is no demand for this (resp. 12). Housing associations have you in the form of frontrunners, platoons and laggards because of the board or management (resp. 8). A respondent confirms this and sees many different ways of soliciting so those concerned with sustainability and others, on the contrary, solicit very traditionally at the lowest price (resp. 1). Another barrier is that housing associations have different (sustainability) goals and some therefore focus on something else such as energy-neutral (resp. 1). Affordability is number one among housing associations, followed by sustainability (resp. 5).

According to one of the respondents, the uncertainty of maintenance is a barrier for investors and housing associations (resp. 5). Another challenge is the residual value of biobased housing (resp. 2 and 9). This requires a new way of residual value method in accounting because of the residual value of biobased houses as these materials can be reused. An increasing number of builders also give a small amount back when concept homes are returned after several years of use. But this is still proving difficult according to one of the respondents because this is something completely new and builders are good at building, not fiscal (resp. 2). Knowledge about this is lacking and another respondent indicates that this is considered quite exciting (resp. 11). A respondent says there is a lack of a second-hand market for flex housing (resp. 2).

The reputation of biobased materials

A major barrier is the reputation of biobased building materials in that they are unfamiliar, unknown, ignorant and uncertain according to multiple respondents (resp. 1, 2, 9, 11, 12, and D1, D2, and D3). There are several myths surrounding biobased construction which are a barrier such as fire safety, moisture problems, pests, logging is bad, low lifetime, more expensive and acoustics according to multiple respondents (resp. 1, 4, 5, 7, 12, and D1). These aspects are considered risks, resulting in a higher price or additional burden of proof which both lead to higher costs. Multiple respondents indicate that this is because of a lack of knowledge and its unfamiliarity and invisibility (resp. 7 and 9). Although another respondent also indicates that biobased construction is becoming more widely known through documentaries on national television, for example, and myths are disappearing as a result (resp. 1). Since biobased materials have to compete against the traditional market with an existing good reputation that is not critically considered, this is a huge barrier.

According to multiple respondents, biobased building is unknown, invisible and uncertain. There are new products that are a bit more exciting than traditional products. The invisibility of biobased construction due to lack of attention also constitutes a barrier because of the lack of people showing a good example. Visibility is not increased by not celebrating success enough. Also because good examples are not set and propagated enough (resp. 1, 3, 9, 12, and 11). This is partly because SMEs are less good at marketing and commerce and the big traditional parties have more money for this. This partly ensures that the biobased alternatives are not as well known, according to a respondent. Another barrier, according to this respondent is the lack of attention to the benefits of biobased building materials such as faster construction time, lower failure costs, savings in maintenance and lower transport costs. These advantages outweigh the higher price for biobased building materials. Other benefits are also not sufficiently understood according to this respondent. Social gains of biobased building are not monetised such as carbon storage, biodiversity and community (D1).

Tenders
Part of the demand is determined by tenders. For instance, according to a respondent, it proves difficult to ask out using the right criteria and formulating them (resp. 1). This barrier overlaps with leadership because the current way of soliciting stems from leadership and focuses, for example, on short-term economic thinking and choices are made based on costs (resp. 8). Also, unrealistic requirements are made in tender according to multiple respondents, respectively, which shows that people have little feeling for the measurement methods. According to multiple respondents, this also deters good parties who can build biobased building (resp. 1 and 2). Health and comfort benefits and other social gains of biobased materials are often not reflected in procurement according to one of the documents (D2). There is a lack of knowledge in housing corporations, municipalities and the government in biobased building according to multiple respondents (resp. 1 and 11).

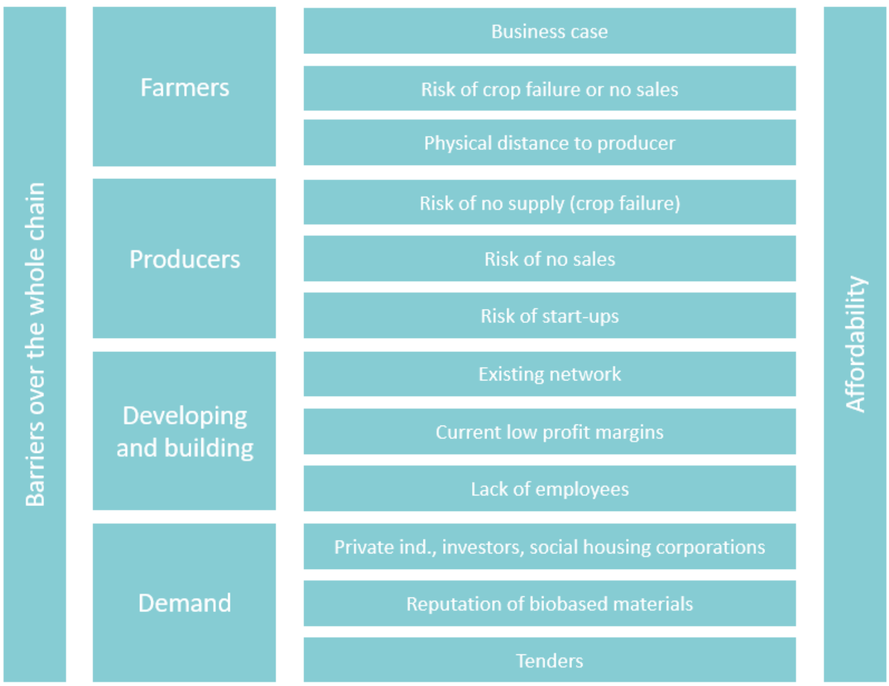

Figure 22 Overview 'Biobased chain and affordability'

4.3 Leadership in the building sector
A major barrier, according to a respondent, is leadership in the construction and real estate sector (resp. 8). By multiple respondents this is described as male, non-transparent, risk-averse, individualistic, directive leadership and inward-looking and money-hungry (resp. 1 and 8). These leaders are focused on short-term economic gains. Multiple respondents indicate that parties are focused on profit maximisation, this is in the system and choices are made based on costs, even though there are social/circular goals (resp. 2 and 10). The current system is economic with neoliberal thinking. This way of thinking cannot change in the short term, a respondent thinks (resp. 10). This is a barrier to embracing and propagating the new way of building. In the system, social values such as

biodiversity, community and carbon storage have no financial value, a respondent says (resp. 12). The intransparency of the traditional construction sector is accepted, while in the biobased sector, people want to know exactly what they are paying for. A barrier may be that the biobased sector is too transparent and less haughty than the traditional sector. Another respondent also cites that people today live in stress and that this leads to a fixed mindset where people have less room for change (resp. 6).

Part of this barrier is people in managerial positions. People working in the Dutch government are generally old men, mentioned a respondent (resp. 6). Most old men become change averse and sceptical. In the places where the biggest changes need to take place for the biobased transition, farmers and builders are old men. In construction, you get to such positions by working your way up according to one of the respondents, so if someone is good at their job, that doesn't mean that person is a good manager, which is a barrier (resp. 8). It is a matter of time before those spots are filled by the new generation, but the planet is not waiting for that. Another barrier mentioned by multiple respondents is the lack of an intrinsic, motivated board or management team to move to biobased building (resp. 9, 10, and D1). Change in this sector is only possible with intrinsically motivated clients or buyers. A barrier among those who are not intrinsically motivated requires another tool such as regulation or a crisis (resp. 9). The province argues that the problem is that, the climate crisis is not tangible and nothing will happen in the short term if we do nothing. People very much like to hold on to the life they have or preferably more. Multiple respondents indicate that the construction industry is very traditional and likes to do things the way they are used to (resp. 3, 4, 5, 8, and D1). This makes it difficult to do something new as they are used to always doing the same thing. Dutch culture is also a barrier in construction because we have a concrete culture and are a brick country because we are a mineral country (resp. 11 and 12). In the construction industry, innovation is seen as a risk and thus avoided (resp. 10). According to multiple respondents, the construction industry is risk averse and prefers to do things the way they have always done (resp. 5, 7, 8, 10, 12, and D2). The traditional sector focuses on the supply side i.e. working with available materials and less on the demand side i.e. which materials best fit the needs of the target group (resp. D2). Banks lack the guts to simply take action (resp. 4). Developers also lack the guts to set biobased targets (resp. 9). Biobased construction is easy for small projects, and in NL there are mainly large area developments (resp. D2).

4.4 Traditional lobby

9 of the 12 parties interviewed and D1 cited the lobbying of traditional parties as a barrier, only a few respondents did not (resp. 2, 7, and 11). According to multiple respondents, this lobby slows down the growth of biobased building materials (resp. 1, 3, 4, and 12) and consists of parties who see biobased construction as a threat to their own operations (resp. 9). The lobby does this through certificates under the heading 'certificates and guarantees' by making them as sharply applicable as possible to their products according to multiple respondents (resp. 5 and 9). This makes it difficult for biobased products to meet these requirements and obtain these certificates. This leads to them not being sold and no guarantees can be given (resp. 10). The lobby also does this by stating that the use of biobased building materials delays the housing task and fuels other misconceptions (resp. D1). In addition, according to resp. 8, the lobby delays by 'cherry-picking' i.e. magnifying small parts of big reports and not looking at the whole and making problems out of this and stalling for time. They are also working against adjusting the MPG (environmental performance building) and the GWPa/MPG2 (resp. 1). There is a focus group developing this requirement and it is proceeding very viscously. This is because of conflicting interests and a lack of experts in this group because the lobby is part of it. The lobby is delaying the process of adjusting the MPG according to multiple respondents. The construction industry is represented in politics by industry associations (resp. 8 and 10). These trade associations exist by the grace of paying members. So these are not the frontrunners of biobased construction

because they have no money for this and only make up a small part of the building sector. As a result, the policy remains focused on the traditional construction sector and thus a barrier to biobased builders. Through window dressing from the traditional parties, their building materials appear good for the environment while the opposite is true (resp. 10). The strong lobby from traditional building can be seen as a barrier but one can also turn it around i.e. lack of a strong lobby from biobased construction (D1).

4.5 Regulation and subsidies

Regulation

Building code

The outdated building code is based on the traditional building economy (resp. 12 and D1). For example, the current building code does not include CLT (resp. 11). Resp. 5 mentions that you are not going to run the risk by applying materials outside the building code.

Eurocode (NEN)

The current Eurocode 5 for timber structures dates from 1995. People are now in the process of adapting it according to one of the respondents, but this takes a long time because various European working groups have to agree with each other (resp. 2). There are also conflicting interests. These groups include various parties such as structural engineers, suppliers, testing authorities, et cetera.

Land use plans

The land-use plan poses several barriers according to interviewees. According to a respondent, there is a barrier in the building regulations (resp. 5). Current land-use plans set traditional requirements for the visual quality plan of houses such as bricks. As a builder, you have to go through a whole permit procedure (incl. costs) if you then want to build biobased because of the biobased appearance. The business case of farmers to start growing biobased building materials is often not feasible partly due to the high land price of agricultural land. There is a gap between agricultural land and 'nature land' in terms of zoning, i.e. land-use plans (resp. 3). This is because natural land is not suitable for growing biobased materials and agricultural land is (often) too expensive. Land-use plan requirements are based on traditional construction (resp. 7 and 10). For example, a wooden floor is often thicker than a concrete floor but the land-use plan states the maximum number of floors and a maximum height of a building. This means that if one builds with wood, one cannot build the maximum number of floors by not complying with the maximum height. This results in one or several fewer floors being allowed to be built than with concrete or steel resulting in less revenue.

MPG

MPG allows biobased materials to score relatively poorly compared to traditional materials resulting in an unrealistic score. This is because stored carbon emissions are not included in the MPG. This barrier has been identified by multiple respondents (resp. 1, 3, 5, 6, 7, 8, 12, D1, D2, and D3). Wood is also rated poorly in the MPG (resp. 2), as it is assumed that 80% of the wood will be burnt after use (End Life Scenario). Also, the measurement methods do not take into account that biobased building materials are renewable (resp. D1). One respondent indicated that the MPG is behind (resp. 10). A low MPG is not requested in general says a respondent (resp. 12) and it is not strict enough for traditional parties who want to build differently according to another respondent (resp. 5). According to multiple respondents, unrealistically ambitious MGP scores are also being asked for (resp. 1 and 2), and this results in parties who tender also lacking in understanding (resp. 2). In this way, these unrealistic criteria discourage 'good' parties. This also shows that the MPG score is not understood. According to a respondent, the determination of the MPG score is therefore difficult to understand (resp. 10). There is a barrier to the incompleteness of the database behind the MPG (resp. 2, 5, and D1). A respondent indicates that the data is compiled by experts including lobbyists (resp. 10). In general is there a lack of knowledge about the measurement methods (resp. 1). According to multiple respondents, there is a lack of knowledge of the MPG among the government and housing corporations (resp. 1, 2, and 12). The existing measurement methods are perceived as complicated (resp. D1). Multiple respondents indicate that the MPG is not checked after realisation, this is partly because the municipalities and housing corporations have no idea how (resp. 2, 6, 12, and D1). The MPG is not checked in permit applications at the municipality, but it is checked by the government for the MIA/VAMIL subsidy (resp. 2). Another respondent says the MPG is never going to be perfect (resp. 1). The focus is on reducing the MPG, which is the steering model, and because of this little attention is paid to the content. More requirements should be set, such as the percentage of non-virgin materials. Influencing the MPG is the lobby, this is also described under the heading Traditional lobby. Multiple respondents mentioned that adjusting MPG takes a long time due to the lobby (resp. 8 and 10). Participants of the focus group for the new MPG are mainly lobbyists whose aim is to protect their companies and not the climate target (resp. 1).

BCI and Paris Proof
A respondent indicates that the BCI is based on the same database as MPG so the same problem as in the MPG is that wood does not score well because of the end-of-life scenario (resp. 1). Even in the Paris Proof method where carbon can be calculated, wood burning is chosen as the end-of-life scenario according to the contractor. There is also a lack of knowledge about the possibilities of the BCI resulting in non-realistic tender criteria.

Subsidies
According to a respondent, farmers are "tired" of subsidies (resp. 3). As they switch to growing biobased building materials, they have to make a large, risky investment because of this, a short-term subsidy is not a solution. The investment for the farmer varies by type of crop and thus by type of building material. For the 'one-year crops', a subsidy could help but not for the long-term crops as farmers then do not have enough confidence that the subsidy will continue according to a respondent (resp. 3). Also, a barrier further down the chain with the producer is the 'Valley of Death' according to one of the respondents (resp. 3). This means that startups can get a lot of grants but at some point, it stops and they then fall into a financial hole. According to a respondent, there is a lack of subsidies to stimulate biobased construction and you need to be good at getting grants (resp. 12). So the barrier is a lack of subsidy for farmers on annual crops, for start-ups the 'Valley of Death' and the difficulty of getting a suitable subsidy.

Government
According to multiple respondents, the regulations are not strict enough resulting in less demand for biobased building materials due to a lack of need from legislation to build biobased (resp. 1 and 7). There is a lack of incentive from the government and parties wait for regulation from the government according to multiple respondents (resp. 12 and D3). According to respondents, a lot of research is mostly being done but real steps are lacking (resp. 1) and indicate a lack of concreteness (resp. 9). The government lacks incentive by not leading, for example, by asking for sustainability criteria in tenders according to a document (D3). According to multiple respondents, a lack of guts in the Dutch government is a major barrier (resp. 1, 4, and 5). The Dutch system is highly organised in terms of spatial development, and this has advantages and disadvantages (resp. 12). The Netherlands has organised everything so well that it now stands in the way of system change to a new, unorganised system, says a respondent (resp. 12). The other side is that it is precise with the current resources that steering can be done, for example, biobased building. This could be the next step. This has to do with the housing crisis, which is a priority according to the government, and biobased construction would slow down house construction according to multiple respondents (resp. 1, 12, and D2). However, the province does see a change in this, e.g. circularity is now an integral part of the policy. Change within

a municipality takes a long time (resp. 10). According to another respondent, governments outsource many functions (resp. 6).

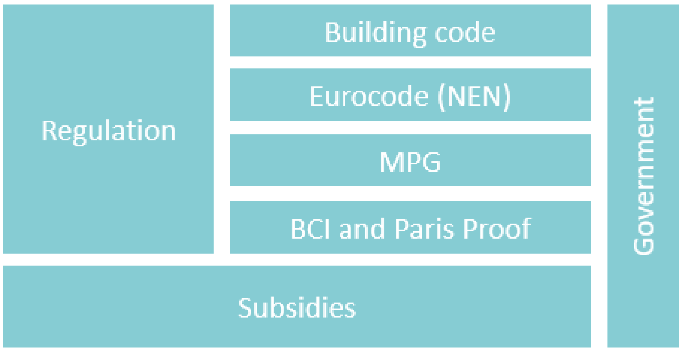

Figure 23 Overview 'Regulation and subsidies'

4.6 Overview and education

Figure 24 is an overview of all themes with education as the overarching theme. According to a respondent, a barrier in education is that old teachers teach using traditional building methods and therefore not biobased (resp. 1). There is a lack of biobased construction in education states multiple respondents (resp. 1, D1, and D2) and another respondent mentioned biobased building is not widely embraced in education (resp. 9). According to another respondent, in universities is less attention to biobased construction, only in temporary courses (resp. 6). Although another respondent says biobased education is on the rise (resp. 2). Also, current workers have not been taught biobased construction in education.

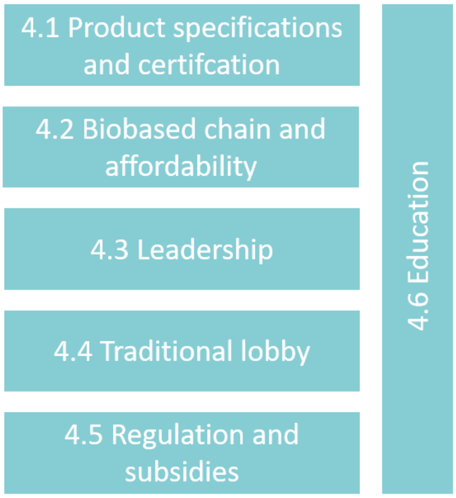

Figure 24 Overview themes

5 Discussion

In this chapter, the sub questions are answered. The results form the basis for the answers to the sub questions and conflicting answers are discussed. It also looks back at the literature review.

5.1 Socio-cultural factors

The first sub question to be answered is "How are the socio-cultural factors influencing the use of biobased building materials?". First, a major barrier is the reputation of biobased building materials in that they are unknown, ignorant and uncertain, which influences the demand for biobased materials. That the reputation of biobased materials creates a barrier that emerged in many interviews and has been noted before in the literature (Markström, Bystedt, Fredriksson, & Sandberg, 2016). Studies of the transition to the CE also mention this factor (Charef, Morel, & Rakhshan, 2021; Wuni, 2022). Additionally, there are several myths surrounding biobased construction that create a barrier, such as fire safety, moisture problems, pests, logging is bad, low lifespan, more expensive and acoustics. These aspects are seen as risks, resulting in a higher price or extra burden of proof, both of which lead to higher costs. This is due to a lack of knowledge and its unfamiliarity and invisibility. Biobased construction is progressively increasing as it gathers attention from national television documentaries, effectively dispelling myths. Since biobased materials have to compete with the traditional market with an existing good reputation that is not critically examined, this is a huge barrier. Biobased construction is unknown, invisible and uncertain. The invisibility of biobased construction due to lack of attention is also a barrier due to the lack of people leading by example. This poor reputation and lack of attention seem to be partly because SMEs are less good at marketing and commerce and have less money for this than the big traditional parties. This leads to a lack of celebrating enough successes and good examples are not set and propagated enough. This partly ensures that biobased alternatives are not as well known. This results in a lack of attention to the advantages of biobased building materials, such as faster construction time, lower failure costs, maintenance savings and lower transport costs. These advantages outweigh the higher price for biobased building materials. Other benefits are also insufficiently understood. Social benefits of biobased construction are not monetised, such as carbon sequestration, biodiversity and health.

Secondly, there is a lack of knowledge about biobased building materials and a lack of knowledge of building engineers and architects about what biobased alternatives exist and how and where to apply them is also confirmed in this study (Visser, Wijk, & Voort, 2015). Education has been confirmed as a barrier in previous research (Göswein, Arehart, Phan-Huy, Pomponi, & Habert, 2022) and so has the lack of knowledge of biobased building (Markström, Bystedt, Fredriksson, & Sandberg, 2016; Markström, Bystedt, Fredriksson, & Sandberg, 2016; Göswein, Arehart, Phan-Huy, Pomponi, & Habert, 2022). The consequences of the lack of education and knowledge about biobased construction cause several other barriers. For example, this causes a lack of workers who can apply biobased materials which is an economic barrier in the chain. Education also forms technical barriers by presenting the traditional way of designing education instead of the new way. Uncertainties about biobased building materials are also formed in education due to the lack of (positive) attention to biobased building. Education also partly shapes the reputation of biobased building and knowledge influences this by dispelling myths. Education can also influence (the way of) leadership. Consequently, there is little research on them and research is lagging. The knowledge is also very fragmented. There is also a lack of knowledge of measurement methods among housing corporations, municipalities and the government. Another barrier at play in education is a lack of attention to biobased construction in education and it has not been widely embraced. However, there are sounds that this is increasing. This is also negatively affected by leadership and lobbying because the old, traditional leaders partly determine education and companies influence education.

A third socio-cultural barrier to the biobased construction sector is the traditional lobby because they want to slow down the growth of the biobased construction sector and they consist of parties who see biobased construction as a threat to their own business operations. The lobby influences certification, guarantees, regulation and the MPG. In politics, the construction sector is represented by industry associations that exist by the grace of paying members. So these are not the frontrunners of biobased construction because they have no money for this and only make up a small part of the construction sector therefore biobased construction is not represented. This leaves the policy focused on the traditional construction sector and thus a barrier for biobased builders. In certification and guarantees, the lobby tries to tailor requirements to their products as tightly as possible, making it difficult for biobased products to obtain the certificates. As a result, guarantees cannot be given for these products and this leads to a lack of demand for them. In addition, the lobby also exerts influence on regulations by, for example, delaying adjustments through 'cherry picking' this is magnifying small parts of large reports and not looking at the whole and thereby stalling for time. They also work against adjusting the MPG and the GWPa/MPG2. There is a focus group developing this requirement and it is proceeding very viscously. This is due to conflicting interests and a lack of experts in this group because the lobby is part of it. The lobby slows down the process of adapting the MPG. Another way in which the lobby delays the use of biobased building materials is by spreading misconceptions such as that the housing task is delayed by applying biobased building materials. Through window-dressing from the traditional parties, their building materials seem good for the environment while the opposite is true. The strong lobby from traditional construction can be seen as a barrier but one can also turn it around, namely the lack of a strong lobby from biobased construction. An earlier study notes that the conservative industry is a barrier and the existence of interest groups lobbying against biobased building (Markström, Bystedt, Fredriksson, & Sandberg, 2016; Markström, Bystedt, Fredriksson, & Sandberg, 2016). Other studies name it indirectly by naming aspects/characteristics of it.

Fourth, an important barrier is the current leadership in the building and real estate sector. Some of its characteristics are described as male, opaque, risk-averse, individualistic, directive leadership and inward-looking and money-hungry. Parties are focused on profit maximisation; this is in the system. Choices are made based on cost, even if there are social/circular goals. The current system is economic with neoliberal thinking. This way of thinking cannot change in the short term. This is a barrier to embracing and propagating the new way of building. In the system, social values such as biodiversity, community and carbon storage have no financial value. The Dutch government generally employs old men, who are change-averse and sceptical. In the places where the biggest changes need to take place for the biobased transition, farmers and builders seem to be old men, who are focused on short-term economic gain. In building, you often get to such positions by working your way up, so if someone is good at his work, that does not always mean he is a good manager, which is a barrier. It is a matter of time before those spots are filled by the new generation, but the planet is not waiting for that. Leadership has not been mentioned as a barrier to biobased building in previous studies, but it has been mentioned in barriers to CE by Wuni (2022) and Habold (2020). A consequence of this is that there is a lack of an intrinsically motivated board or management team to switch to biobased construction. Change in this sector is only possible with intrinsically motivated customers or buyers. A barrier among those who are not intrinsically motivated requires another tool such as regulation or a crisis. The climate crisis is not tangible and seems far away, which means that few people feel responsible for it, resulting in that nothing will happen in the short term. People very much like to hold on to the life they have or prefer even more. This barrier has not previously been identified in research on barriers in biobased construction. However, this barrier has been identified in research on barriers in the CE by Wuni (2022). However, this barrier was named as very important by several respondents. This barrier is also related to the barrier of leadership.

The fifth socio-cultural barrier is that the Dutch building culture is an obstacle to building because we have a concrete culture and are a brick country because we are a mineral country. The construction industry is very traditional and likes to do things the way they are used to. This makes it difficult to do something new because they are used to always doing the same thing. The intransparency of the traditional construction sector is accepted by society, while in the biobased sector, people want to know exactly what they are paying for. An obstacle may be that the biobased sector is too transparent and less haughty than the traditional sector. In building, innovation is seen as a risk and therefore avoided. The construction industry is risk-averse and prefers to do things the old way. The traditional sector focuses on the supply side, i.e. working with available materials, and less on the demand side, i.e. which materials best suit the needs of the target audience. Banks lack the guts to simply take action. Developers also lack the guts to set biobased targets. Biobased building is easy for small projects, and in NL there are mostly large area developments. Studies on barriers in biobased building materials do not focus on the Netherlands, therefore it cannot be confirmed by previous studies. In other countries, this is not a barrier according to previous studies, including in the transition to the CE.

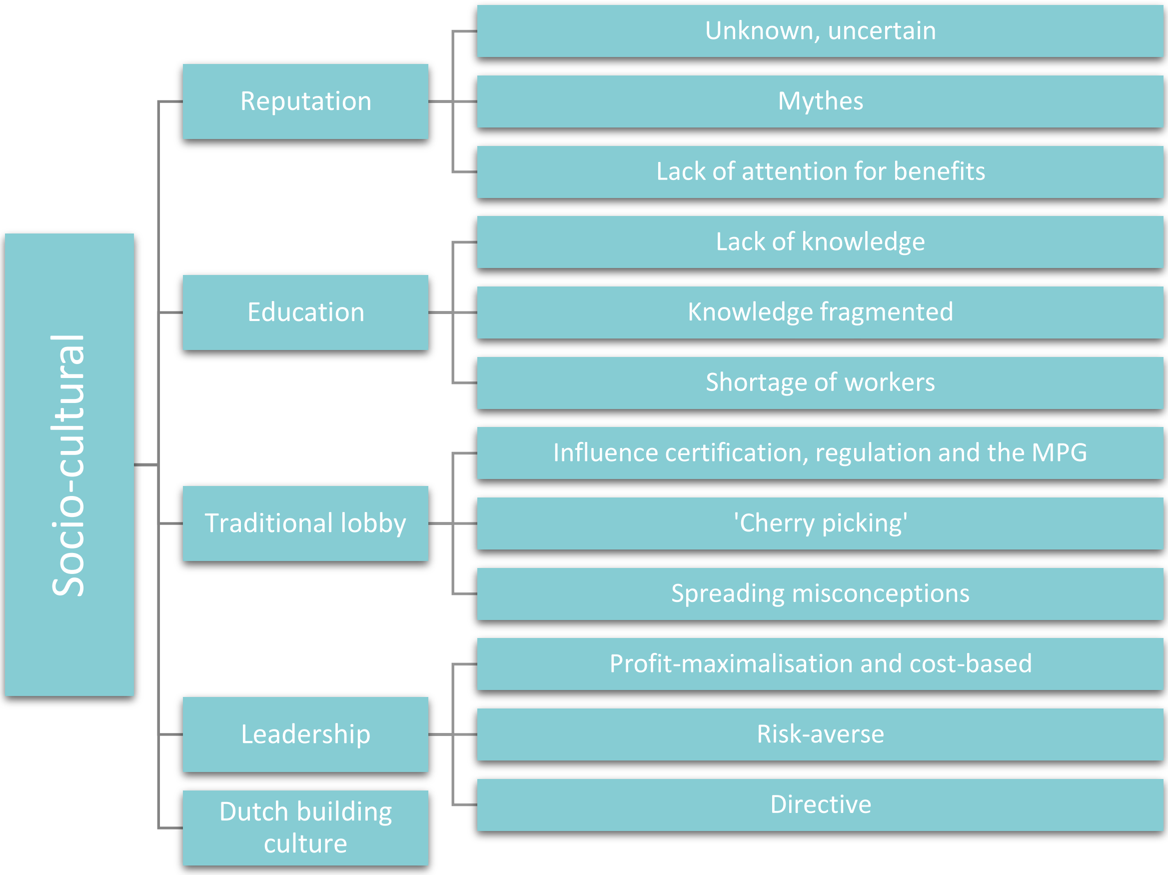

Figure 25 Overview socio-cultural factors

5.2 Technical factors

The second sub question to be answered is "How are the technical factors influencing the use of biobased building materials?". There are several technical and technological barriers. The first barriers are linked to the specifications of biobased materials. Biobased materials have different specifications from traditional building materials, which affects workability and requires a different application. For example, biobased insulation material is thicker than traditional insulation material. That the applicability of biobased building materials is a barrier is doubly confirmed as it appears in all the literature and is evident from the data (Visser, Wijk, & Voort, 2015). Also, the acoustics are somewhat less than with traditional materials, mainly for wooden structures. In the Netherlands, people are used to very good acoustics. Fire safety is another barrier in wooden high-rise buildings. From the literature review, acoustics, fire safety, fire requirements, and the uncertainty of the quality of materials were also found to be barriers (Markström, Bystedt, Fredriksson, & Sandberg, 2016). For some traditional materials, it is difficult to find a comparable biobased alternative. Another barrier is the difficulty in finding good biobased alternatives to traditional building materials. This could be a consequence of the economic factor of the lack of marketing of biobased products which has also been identified by several studies. These factors are also commonly cited factors evidenced by previous studies on the CE. The technical factors are entirely reflected in the literature and thus confirmed. The unfamiliarity of maintaining the materials is also a barrier to application. This barrier is also confirmed in this study to be a barrier and this is also mentioned in other studies (Markström, Bystedt, Fredriksson, & Sandberg, 2016) (Visser, Wijk, & Voort, 2015). These barriers stem from the traditional design of traditional materials and are mainly cited by practitioners. However, experts think differently and claim that there are no technical or technological barriers. According to them, there are no technical barriers but the traditional way of designing is the barrier. One has to design in a new way from biobased materials and use complementary applications. That a new way of designing is needed is also confirmed by the research of Yadav and Agarwal (2021). Technical factors thus appear to play a role in practice as a barrier to choosing biobased materials. Theoretically one can apply biobased materials, but this requires a new way of designing.

A technological barrier is the lack of data on biobased building materials as input for regulations, leading to regulatory and certification barriers, which are more under institutional barriers. The barrier around data has also been identified earlier by this research. The shortage of professionals is linked to a lack of biobased building in education and a lack of knowledge among workers which have been confirmed in other studies (Göswein, Arehart, Phan-Huy, Pomponi, & Habert, 2022; Markström, Bystedt, Fredriksson, & Sandberg, 2016). There is also a shortage of professionals who can apply biobased materials, such as carpenters and structural engineers who can calculate wooden structures. This barrier is caused by the education barrier (socio-cultural barrier) because that is where these people are trained, and linked to the barrier in the chain. After all, that is where the effects are felt. The technical barriers overlap with the institutional barriers because that is where regulations on technology are developed. There is also a lot of overlap with economic barriers because that is where the effects of the technical barriers are felt in the chain and affordability. For example, to make a high-rise building fire-safe.

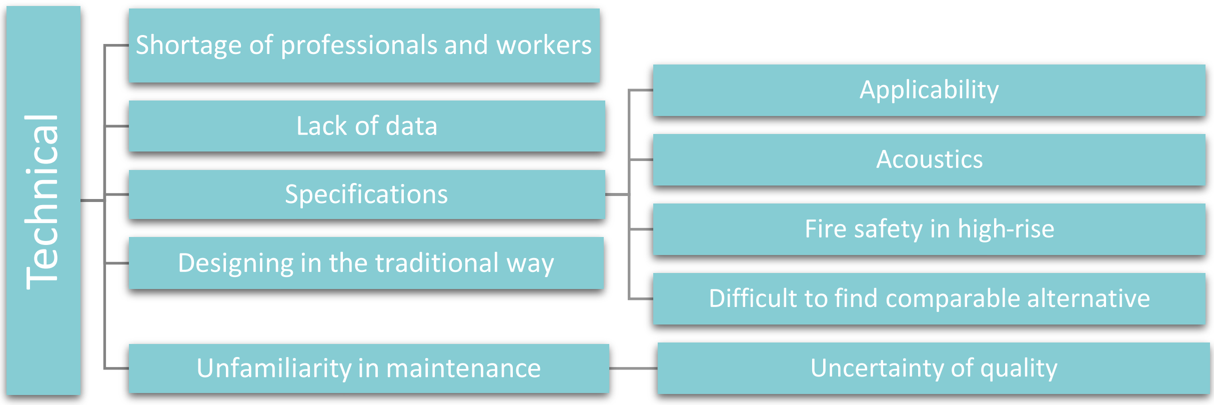

Figure 26 Overview of technical factors

5.3 Economic factors

The third sub question to be answered is: "How are the economic factors influencing the use of biobased building materials?" The first economic barrier is the affordability of biobased materials. A barrier in choosing biobased building materials is price, as those are generally more expensive than traditional building materials, this is confirmed by Yadav and Agarwal (2021). This was explained through the following 4 explanations. First, as the sociological barriers showed that product choice is cost-based, so the basis of this barrier lies in product choice, which is a sociological barrier. So in this sense, the barrier is how this choice is made rather than the cost itself. Second, it can be said that a barrier is not the price but the comparison material, because a question is; can it be compared with traditional building materials? And is it being compared in the right way? The social benefits of biobased building such as health benefits and carbon capture are not deducted from the price of biobased products. It is also claimed that biobased products are less expensive than traditional products but the barrier is the current way of designing as mentioned in the technical factors. By designing in a new way, fewer materials are needed and biobased materials are very light reducing the need for the amount of foundation. Yadav and Agarwal (2021) confirm there is a new way of thinking is needed which leaves the current standards behind. Third, traditional building materials are cheaper because this market is highly efficient due to its long-standing and optimised nature. Fourth, the traditional market operates on a huge scale compared to the biobased market, which is a niche market with a lack of infrastructure and organisation, this is confirmed in the literature (Göswein, Arehart, Phan-Huy, Pomponi, & Habert, 2022). This market contains learning costs and risks which are no longer present in the traditional sector. The biobased market, therefore, needs time to develop. The other side of this story is that the traditional sector is too cheap and brings disadvantages that are not monetised.

There are several economic barriers to the emergence of the biobased chain. The biggest barrier is the pointing at each other which resembles a 'chick-and-egg story' because this emerged in several interviews. For instance, farmers say they are held back by a lack of buyers. While producers, the farmers' buyers, say they are not starting because of a lack of supply of biobased crops. Thus, parties point to each other to take the first step, with the result that nobody takes the first step because of dependence on each other. This is new in the literature but emerges from several interviews. Chain knowledge is asymptotic which is a barrier because this causes a lot of ignorance about the availability of materials and other information, this is confirmed in the literature (Markström, Bystedt, Fredriksson, & Sandberg, 2016). The lack of chain knowledge may be part of the aforementioned 'chicken-and-egg story'. According to Wilk (2022), it is therefore important to increase the availability of biobased building materials and make consumers aware of the possibilities in them. Also, waiting for regulations from the government is a barrier. This can also be seen as part of the 'chicken-and-egg story' because this too is pointing to another party, also this can be a lack from the government and thus an institutional barrier but the consequence is in the chain. The barriers mentioned above could also be seen as sociological barriers because if the entire sector structurally thinks like this and it is not an economic problem. Also, a big obstacle is that people see what cannot be done only that the chain is incomplete and therefore it is not possible. Another barrier is the fragmentation of the chain making it a niche market due to lack of organisation and good infrastructure. The biobased market is less mature and lacks cooperation in the chain. Parties are trying to reinvent the wheel. A large part of the chain consists of start-ups that need time. And if everyone keeps going for the cheapest (traditional) then this will remain the cheapest. In the following, personal barriers are named for each actor in the chain. These above barriers seem logical at this time of transition, these will resolve as time goes on.

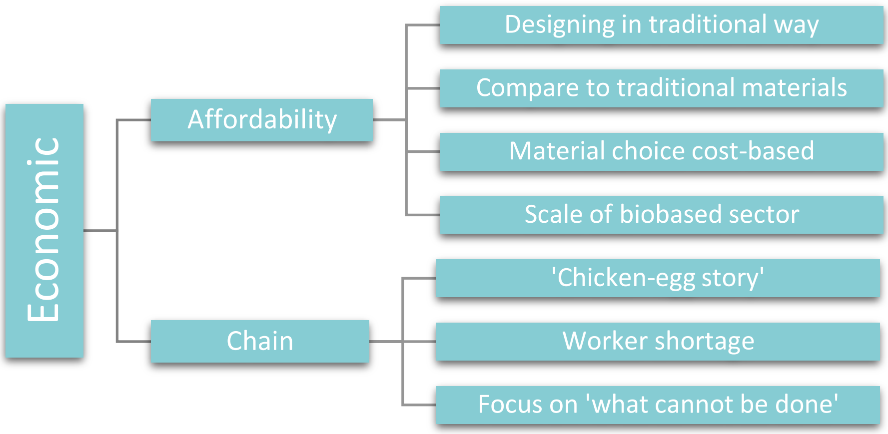

Figure 27 Overview economic factors

Farmers

Little could be found in the literature about barriers to farmers so the information below is new and emerged from an interview. This may be because the chain does not yet exist and is now creating itself. Farmers will only convert according to when growing biobased products is a viable business case making the unviable business case a barrier. Currently, returns from traditional crops are higher than those from growing building materials. Risks also affect this, the risks of crop failure and no sales. A farmer starts this when he is assured of good sales. Also, some crops, such as bulrush, require high investment costs, which is an additional barrier. The physical distance between farmer and producer is a barrier for some products. For instance, for cattail, it is important to process it as locally as possible, while wood from, say, Scandinavia can easily be shipped to the Netherlands because it is bulk. This aspect also affects the feasibility of the business case. Although importing biobased building materials is seen as bad for the environment, which is also a barrier. The reason why this part of the chain is still missing and the business case has also not been studied. Among farmers, not many barriers seem to exist, only the business case, which is a logical barrier. This barrier seems to be resolved as demand increases, so this barrier can solve itself.

Producers

The risk of crop failures preventing the supply of biobased materials is also a barrier for producers. This risk is a risk to the farmer and not the producer. In addition, the question is whether this is a risk or whether it is a lack of knowledge or unfamiliarity. In addition, there is a lack of processing parties and factories. A manufacturing company will not grow without certainty of sales. Biobased producers focus on their own products and not on the holistic perspective. Another reason why there are not enough processing parties is the 'Valley of Death', see the heading subsidies. There is also a lack of structural engineers who can calculate wooden structures. It is difficult for start-ups to compete with the current market due to a lack of capital and expertise. To get started, one has to make a hefty investment. Standardisation and off-take guarantees require constant quality, delivery and off-take guarantees and logistics, and this is difficult for building products from agricultural and natural waste streams. Besides this, marketing risk is also a barrier. Earlier literature research also mentioned that there is too little marketing from producers for biobased materials (Markström, Bystedt, Fredriksson, & Sandberg, 2016). This may therefore account for the barrier of lack of good biobased alternatives to traditional building materials.

Developing and building

A barrier is an uncertainty about the supply of biobased building materials. There is also a lack of a good biobased alternative for some materials such as good insulation because it is little available and expensive. This could also be a consequence of asymmetric knowledge in the chain. Another barrier is the lack of experience in building with biobased materials. A contractor does not often propose biobased construction because of a need for comfort, see sociological barriers. Contractors' current low-profit margins are also a barrier, as this leads to risk-averse behaviour. There is also a lack of knowledge among buyers if the biobased offer which leads to uncertainty about biobased materials, resulting in additional proof costs, and building on the sure side, also leading to higher costs. Another barrier is the existing network, the relationships in the construction industry where people work with standard relationships to ensure guaranteed material flows. The other side of this is that one already has a chain, and can transform it together into a biobased chain. Contractors and construction companies lack knowledge about calculating timber structures. Lack of knowledge among building engineers and architects is confirmed in the literature (Markström, Bystedt, Fredriksson, & Sandberg, 2016). Especially calculating the details proves to be an obstacle, as projects are becoming increasingly complex. Complexity is increasing rapidly, with the pitfall being that knowledge is not keeping pace. There is a shortage of carpenters, draughtsmen and structural engineers and the demand for these will only increase. There is also a shortage of employees with experience in working with biobased building materials. The cause of labour shortages lies in the sociological barrier, namely education.
Previous literature confirms that contractors see a risk of additional costs if the biobased materials fail within the warranty period. Small profit margins among contractors as a barrier are also confirmed in the literature in this regard. The lack of knowledge among structural engineers and architects on how and where to use them is also confirmed as a barrier (Markström, Bystedt, Fredriksson, & Sandberg, 2016).

Demand

There is little in the literature on the demand side for biobased buildings. Below is what has emerged from the data. Influencing demand is the reputation of biobased building materials, more on this under the heading sociological barriers. A barrier in demand from private individuals is the housing shortage as this lowers their housing requirements as housing is a basic need. As a result, demand from private individuals has not increased even though there appears to be a need for it. Only private individuals who have the money to build a house themselves can choose biobased materials but this is only a small part of the market. Banks can indirectly influence this by, for example, giving interest rate discounts on mortgages for biobased houses. But banks lack the guts to take this step except for a few pioneers. Pension funds lack sustainability targets, so demand for biobased homes is not picking up. While there is also noise that investors are keen to add biobased homes to their portfolios. After all, pension funds get points if they invest in green homes and see a future in biobased construction. Investors mainly see barriers when thinking about biobased building such as filling in that it is more expensive without calculating or thinking there is no demand. There are housing associations in the form of frontrunners, platoons and laggards because of the board or management. There are many different ways of tendering so those who are engaged in sustainability and others just very traditionally tendering for the lowest price. Another barrier is that housing corporations have different (sustainability) goals and some therefore focus on something different such as building energy-neutral houses. Affordability is the most important aspect among housing corporations. Tenders are also part of the demand, barriers in this are discussed under institutional barriers. More research needs to be done on the above output to confirm this. Also, many different enquirers are making it difficult to generalise. Why there are different voices on the demand side for biobased building materials is unclear.

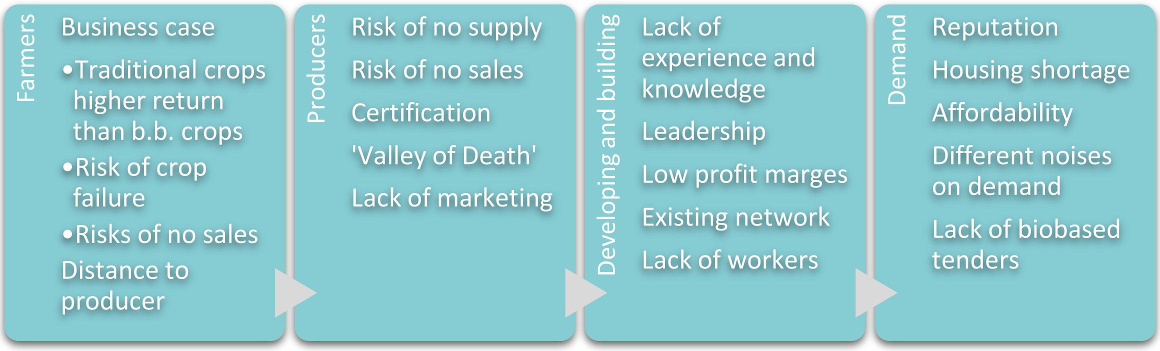

Figure 28 Overview factors in the chain

Tenders

There are also some barriers in the tenders, which determines part of the demand. For instance, it proves difficult to ask for and formulate the right criteria. This barrier overlaps with leadership as the current way of soliciting stems from leadership and, for example, focuses on short-term economic thinking and choices are made based on cost. Also, unrealistic requirements are set in the tender showing little sense of measurement methods. This also deters good parties who can do biobased construction. Health and comfort benefits and other societal benefits of biobased materials are often not reflected in tenders. The impact that tenders have on biobased building has not previously been demonstrated in previous studies. This may be because it can be pushed under the barrier of leadership or the government because these aspects lead to the lack of biobased tender criteria. Tenders are tendered by government or market players. The reason tenders are not biobased from the government is caused by institutional barriers, written out later in the conclusion. For market parties, this cause is the socio-cultural barrier of leadership and culture in traditional construction. Economic factors consist of chain barriers and affordability. The affordability of biobased materials can be seen as debatable, practitioners see this as an immediate barrier while others also indicate that it is due to the traditional way of designing. In the chain, the biggest barrier lies in pointing at each other, the 'chicken-and-egg story'. Furthermore, different actors in the chain have separate barriers. To set up this chain, incentives will be needed.

5.4 Institutional factors

The fourth sub question to be answered is "How are the institutional factors influencing the use of biobased building materials?". There are several regulatory barriers. First, certification is a big barrier because it emerged in many interviews. To obtain a permit, one must build according to the building code and this includes using certified products. Also, a requirement for warranties is the use of certified products. Since the construction industry is risk-averse, people opt for certified products. For new biobased building materials, it is difficult to get certificates because of the cost, duration and facilities required. It is also difficult to determine the best time to get the certificates as the product is under development and continuously improving. Another barrier herein is that the requirement for these certificates is very much focused on the requirements of traditional materials. These requirements are set by the traditional construction lobby to protect their own business. It is therefore increasingly difficult for biobased building materials to obtain certificates. Also, there appear to be few/no warranty and insurance systems for biobased materials, which is a major barrier. The barrier of certification is not reflected in the literature review, although it does appear to be an important barrier from the interviews. However, the literature does show that it is difficult to meet certain requirements for fire safety and acoustics, this may be a consequence of the barriers mentioned above (Markström, Bystedt, Fredriksson, & Sandberg, 2016).

The second barrier is in the Eurocode and Building code. Namely, it is based on traditional building materials so CLT, for example, is not included. As the construction industry is risk-averse, it will not build outside the building code. Another barrier is the Eurocode (NEN), which dates from 1995 and is also based on traditional building materials. People are working on updating this but many parties have to agree. This is a viscous process because of conflicting interests in which the traditional lobby plays a delaying role.

A third institutional barrier is formed by the land-use plan. The building regulations are based on traditional construction which has a negative effect on biobased construction for example in building height. The aesthetics requirements focus on the traditional appearance of houses, which means biobased construction is not allowed to be visible and is, therefore, a barrier. This barrier is also found in an earlier study (Markström, Bystedt, Fredriksson, & Sandberg, 2016). The government, specifically municipalities, directly influence the land-use plan and thus causes this barrier. The land-use plan is a barrier to the biobased farming business case. Because land zoned for agriculture is too expensive for a feasible business case to grow biobased building materials and land zoned for nature is affordable but cannot be used for this purpose. So there is a gap in the land use plan. This was only cited in one interview and is not found in the literature, therefore not reliable. It is on the other hand considered to be worth seeking out further.

Fourth, measurement methods are a major barrier and specifically the MPG, the environmental performance building. This is the regulatory measurement method used by the Dutch government as a measure of a building's sustainability. This is because the MPG allows biobased materials to score relatively poorly compared to traditional materials, resulting in an unrealistic score. This is due to the End Life Scenario that is part of the score. For instance, the calculation assumes wood is burned at the end of its lifecycle, releasing all its carbon. Another bias lies in the fact that carbon storage is not included in the score. The renewability of materials is also not included in the MPG, which plays a major role in the very low, not strict scores demanded. This and the unrealistic, high-demand scores keep traditional parties from building biobased. This results in 'serious' biobased parties not tendering. The MPG score is therefore difficult to understand and complicated, and the database behind it is incomplete. This data is provided by experts, partly from the lobby, this also has a negative influence. There is also a lack of knowledge among government agencies and housing associations. As a result, the MPG calculation does not appear to be checked in permit applications. There is also a lack of quality control during and after realisation, allowing people to do whatever they want after the permit application. The focus is not on the content but on lowering the MPG. A new MPG (MPG-2) is being developed but the traditional lobby is at the table on this and is a barrier, for further clarification see the heading lobby. BCI and Paris Proof are also partly based on the MPG calculation. Yadav and Agarwal (2021) confirm in their research that there is a lack of good measurement methods to demonstrate the benefits of biobased construction. Research by Wuni (2022) on the transition to the CE also cites this as a barrier. As this barrier was mentioned in almost all interviews, this appears to be a major deficiency in stimulating biobased building.

The fifth barrier is related to government. Government regulations are not strict enough which creates a barrier by reducing demand for biobased buildings. There is a lack of incentive from the government to protect societal values. A lot of research is being commissioned by the government but concrete steps are lacking. People want to be sure of everything before intervening. There is a lack of examples the government can set in this transition by asking for biobased products with sustainability criteria in tenders. There is a lack of guts from the government to intervene. What is causing the government's attitude may be the housing crisis, which the government says is a priority, and biobased construction would slow down housing construction. There are also some barriers to subsidisation from the government. The lack of government incentives is evident from several previous studies on barriers in biobased building (Markström, Bystedt, Fredriksson, & Sandberg, 2016; Göswein, Arehart, Phan-Huy, Pomponi, & Habert, 2022). 1xThis research also reveals details of in which areas these incentives are missing such as farmers. Also in the transition to the CE, there was a lack of policy regulation and approach because it is too complex and lacked support from the government (Charef, Morel, &

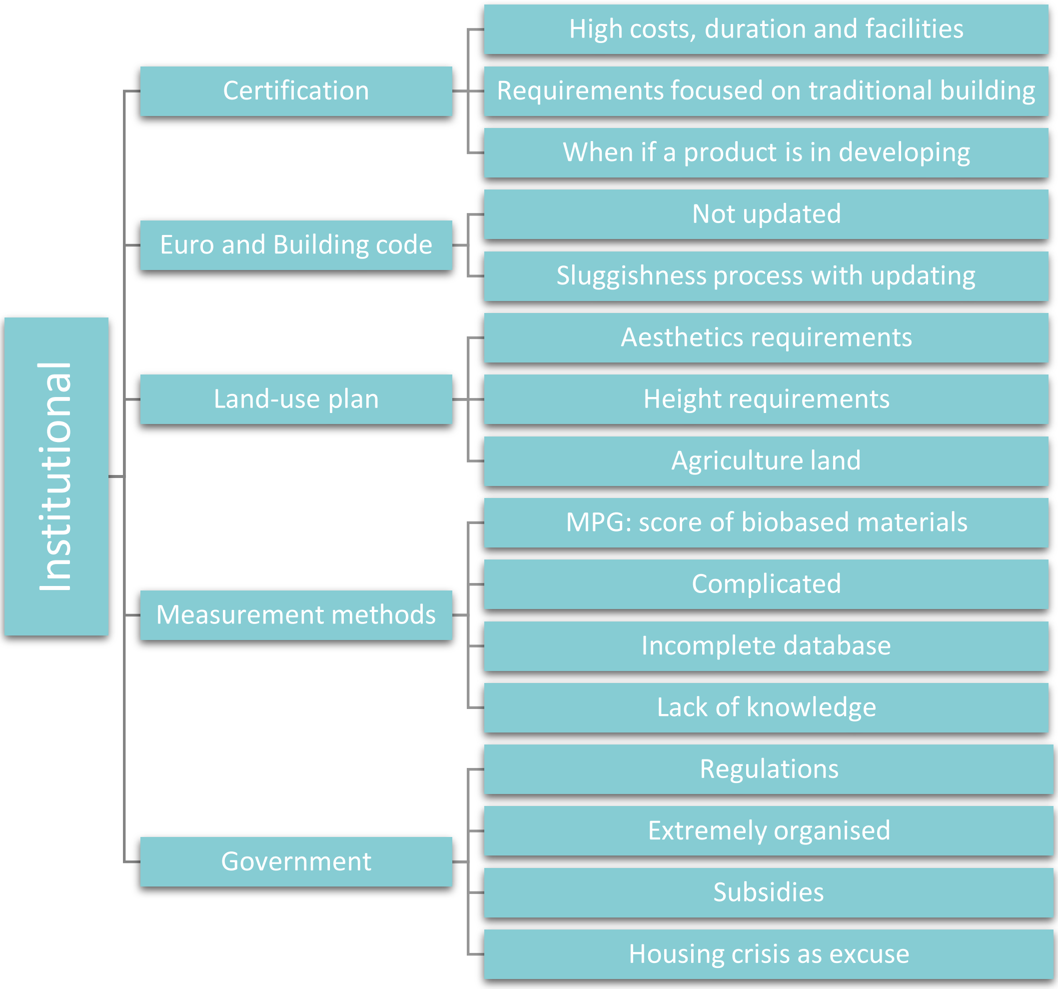

Figure 29 Overview institutional factors

Rakhshan, 2021). Habold (2020) also identified a lack of governmental support in the transition to the CE. The Dutch system is extremely organised, which now stands in the way of a system change to a new, unorganised system. The other side is that biobased construction can be steered precisely with the current, already existing resources. Since a barrier is a viable business case among farmers, subsidies seem to be a solution. A general barrier in this is that farmers are fed up with subsidies. For farmers, there are broadly two types of crops for biobased building materials; annual and perennial crops. For annual crops, subsidies could be attractive but less so for perennial crops. For instance, a farmer has to make a risky, large investment which is reversible and therefore requires a subsidy for years. The barrier in this is that farmers have little faith in politics. However, subsidies could be used with other parties in the chain to indirectly create demand among farmers. Another problem is the 'Valley of Death' for start-ups. Start-ups get subsidies up to a certain size of the company, these suddenly fall away when the company gets bigger and the company falls into a financial hole. And for the whole chain, a barrier is the difficulty of getting a suitable subsidy. Wuni (2022) also confirms this, adding that financial support mechanisms such as grants from the government are lacking. Institutional barriers are mainly in Dutch laws and regulations such as the land-use plan, certification, the building code and the MPG, which are part of a hugely organised and efficient system. The downside is that it is difficult to do things differently and deviate from what the system is set up for. Which results in the system working against itself.

5.5 Further research

This chapter lists what needs further investigation. As this study was of an exploratory nature, this research provides the basis for new studies. For this reason, this chapter could be infinitely long, so the most important aspects have been extracted and listed here. Further research is needed to confirm this research. Research would also be conducted separately by typology or into the links between the typologies, and how they relate to each other. A 'new way of designing' is often mentioned but a definition of this is lacking, this needs further research. The differences between traditional design and the new way of designing might also be interesting to research as to how this contributes to biobased construction. Another new aspect is the 'chicken-egg story', which emerged from many interviews and is therefore interesting for further research. There also appears to be little information available and knowledge about farmers as part of a biobased chain, partly because this is new. Farmers only want to grow biobased building materials if they have a feasible business case. Research into such a business case is lacking, especially what influences this business case. The reputation of biobased construction is another interesting factor directly influencing demand for biobased construction. Yet little appears to be known about this and therefore follow-up research is needed. Leadership appears to be a barrier in the transition to biobased construction, but very little is known about this. Therefore, this is an important topic for follow-up research. The influence of the Dutch government on biobased construction would be another interesting aspect to investigate further as several tools emerge from the data. Research into these tools is lacking, while they have a lot of influence on biobased construction. Specific research into tender (criteria) is also needed to get a better picture of how tender (criteria) can stimulate biobased construction. In the next chapter, based on the factors, recommendations are made for practitioners and clients. Further research is needed to find out which factors can stimulate biobased construction and to what extent they have an effect.

6 Conclusion

This research dealt with the barriers to the use of biobased building materials. This chapter answers the main research question and will discuss the interpretation of it, the research limits and the recommendations.

6.1 Barriers to biobased building

This chapter answers the following main question:

"What are the current barriers to the adoption of biobased materials and how do they influence uptake in the Netherlands?"

First, several **socio-cultural** factors influence this. The reputation of biobased materials is not optimal because it is unknown, ignorant and uncertain, which affects the demand for biobased materials. The focus is mostly on myths such as moisture problems, acoustics, fire safety, etc. As a result, there is a lack of attention to the positive effects of biobased construction such as carbon capture, biodiversity and health. The lack of a good reputation is partly due to a lack of knowledge, which is lacking but also very fragmented. This is because there is a lack of marketing and commerce for this and in education there is a lack of attention to biobased construction, which also results in a shortage of employees who can work with biobased materials. These aspects are influenced by a lobby from the traditional construction industry. This party wants to slow down the growth of biobased materials to protect its operations. They influence certification, warranties, education, regulations from the government, the MPG and the reputation of biobased construction. Construction representatives consist of paid members and since biobased construction is only a small part of the construction industry, they are not represented here. Another way they exert influence is by spreading misconceptions that biobased construction slows down housing construction and that the use of biobased materials is not desirable with the current housing crisis. Another barrier is leadership, meaning that most leaders in construction tend to be old men who are risk-averse, non-transparent, individualistic with directive leadership, inward-looking and profit-oriented. The current capitalist, neoliberal, economic system is not open to change and short-term thinking. Most leaders in construction work themselves up so are not necessarily good at managing. The intransparency from the traditional world is accepted while transparency is expected from biobased construction. A requirement for biobased construction is an intrinsically motivated board or management team. When this is lacking, other tools such as regulation or a crisis are needed. The current, traditional building culture stems from the culture of the country; a mineral country. The traditional construction industry does not like to change and continues to do things as they have always done them. Innovation is seen as a risk and therefore avoided. Different parties like governments and banks lack the guts to take action.

There are also **institutional** factors affecting the transition to biobased construction. First, certification is a barrier, which is necessary for guarantees. Indeed, these are difficult to obtain for biobased products because certification takes time, money and facilities, and it is difficult to determine the right time as the products are under development. Added to this, the requirements of certificates are focused on traditional products. Second, the Eurocode and the building code affect this as they are outdated and do not include biobased construction such as timber construction. A third factor is the land-use plan, which is geared towards traditional building heights while the specifications of biobased materials are different, thus having a negative influence. Also, building regulations are geared towards traditional building appearance such as bricks. Fourth, current measurement methods such as the MPG are a major barrier. This is because biobased materials score relatively poorly compared to traditional materials due to the end-of-life scenario. Also, the MPG is complicated and the database behind it is incomplete. The fifth factor is the government, as there is no incentive from the government. The government prioritises the housing crisis and thinks biobased construction would have a delaying effect on this. Also, the Dutch system is extremely organised, which now stands in the way of change to a new, still unorganised system. Subsidies are also an institutional barrier due to the lack of them and subsidy fatigue among farmers and the 'Valley of Death' among producers.

There are also **economic factors**. For instance, biobased building materials turn out to be more expensive than traditional building materials. First, people design from specifications from traditional materials, making it more expensive to 'replace' with biobased materials while if they design from biobased materials, this would not be a barrier. Secondly, people compare it to traditional materials, which can be produced extremely efficiently without including the negative effects on the price. Thirdly, material choices are made based on cost, this is also a sociological barrier. Fourth, this is due to the current scale of the biobased market involving learning fees and a lack of organisation and infrastructure. The economic factors are also about the barriers in the chain. The biggest barrier in this is the 'chicken and egg story' where parties in the chain only point at each other as a reason not to start, also many parties are waiting for regulations from the government. Another shortcoming is that there is a lot of focus on what cannot be done and the current state of the biobased chain, but time will solve this. There are currently barriers in the chain such as supply and demand and worker shortages with the right skills. Furthermore, the barriers in the chain are mainly down to other typologies such as subsidies to institutional, mindset and worker shortages. The demand side also plays an important role in the emergence of the chain. There are different voices on this. However, there are possibilities to increase it, such as higher sustainability requirements or through tenders.

There also appear to be several **technical factors**. The specifications of biobased materials are different from traditional materials, which can lead to different fire safety and acoustics and this constitutes a barrier. The unfamiliarity of maintenance also appears to be a barrier. These barriers are seen by practitioners. However, experts think differently about this and think this barrier is created by the traditional way of designing. To make the transition, it is necessary to design in a new way, from biobased materials instead of traditional materials. There is also a lack of data which limits measurability resulting in limited realistic MPG.

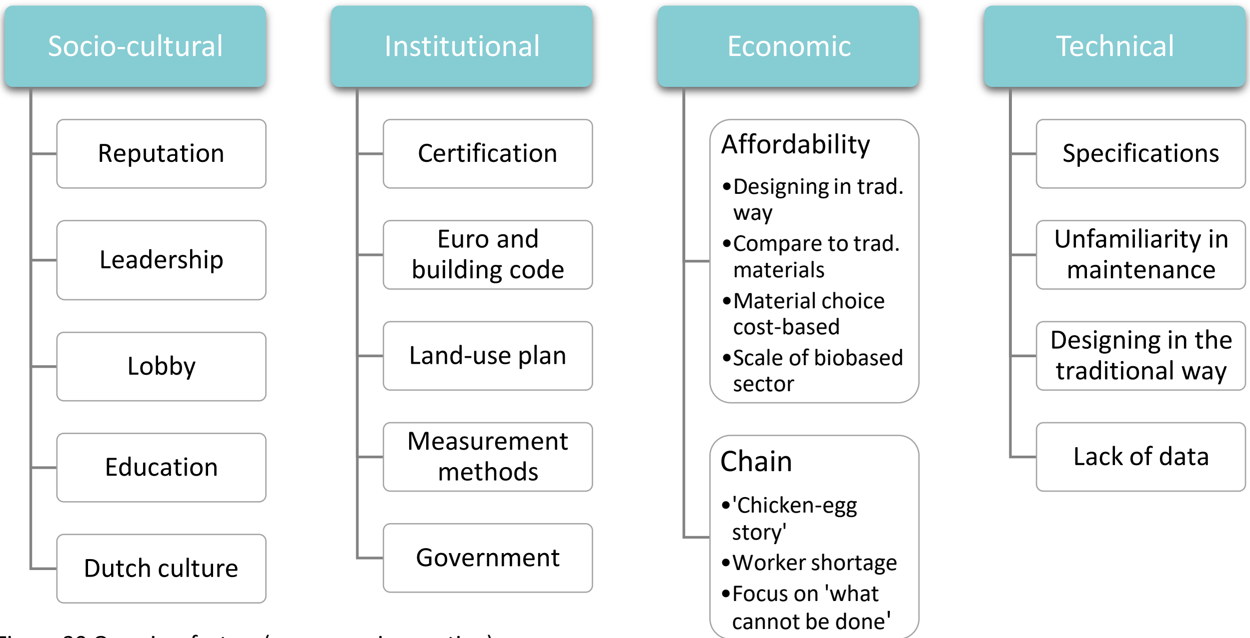

Figure 30 Overview factors (answer main question)

6.2 Stimulation of the use of biobased materials

Promoting biobased construction can solve the problem of high levels of carbon emissions and the housing crisis. This is possible because by building with biobased building materials, houses can be built and carbon can be stored at the same time. Its purpose is to provide advice to practitioners. Following this, advice specific to the client, Alba Concepts, will be given. This chapter answers the following intervention question, to solve these problems:

"In what way(s) can the use of biobased materials in the building sector be stimulated?"

6.2.1 Recommendations for practice

Socio-cultural

The traditional lobby appears to be a barrier to biobased construction, but one can also see this the other way around; it is a shortcoming that the biobased industry does not have a lobby. This lobby should therefore be set up and this sector should be seen separately from the traditional sector as these sectors have different interests. Leadership in the construction sector needs to change. Future leaders should have more feminine characteristics where leaders live from the inside out with great self-awareness (thoughts, feelings, emotions, values). As a result, economic interests will no longer come first and the process and community will receive more attention. The reputation of biobased construction will have to be improved, this can be done by making education cover this more and more positive and putting biobased projects in better sunlight by celebrating successes. Also, if, producers of biobased products invest more in marketing, awareness and reputation can improve. Research and knowledge also influence the reputation of biobased construction so this can also improve it. Adjustment of the traditional profit-oriented construction sector is difficult, this can only be influenced by economic incentives and these must come from the government (institutional). However, the government can monetise social values, giving companies economic incentives to achieve social goals.

Institutional

Generally speaking, the chain can be influenced in two ways: the first is by creating demand, which makes the rest of the chain develop by itself. The second way is by creating incentives in the chain so that the chain develops that way. The government can be hugely influential in accelerating the increase in the use of biobased building materials in various ways. The government should start to see that biobased construction can actually accelerate housing construction instead of slowing it down. The government can do this through the land-use plan, welfare and measurement methods. For instance, an adjustment in the MPG is necessary to make biobased building materials compare better with traditional building materials by adjusting the end-life scenario. Further research needs to be done on many aspects and this research can serve as a trigger, this is further described in the heading 'Further research'. Furthermore, a transition needs to take place in education, changing the content of education and training more people who can work with biobased building materials. This may also lead to a better reputation for biobased materials.

Economic

To better get biobased building materials visible on the market and reduce ignorance about their availability, it is important to improve the marketing of biobased building materials. It is difficult for start-ups to invest in marketing with the limited money they have but they can use free or low-cost options such as LinkedIn. Cooperation can also be sought in this to, for example, share marketing costs. More collaborations between biobased parties are a good idea anyway to build a network this way. This could start with low-threshold, small network events for biobased construction. Here, traditional parties interested in biobased construction can discover it and gain more confidence. It is also important to change the current economic system. Indeed, this system is profit-driven and takes limited account of social values. It would help if carbon were monetised and those who store carbon were paid for it. This could be an incentive for farmers as it positively affects their business case. It would also have a positive impact on the affordability of biobased building materials compared to traditional building materials as they do not have this advantage.

Technical
Solving many barriers requires a new way of designing. Currently, designs are mainly based on traditional building materials; this should be done using biobased building materials. The basis for this lies in education; in addition, companies need to start working with this, for instance through courses. It is very important to collect more data on biobased construction. In this way, uncertainties can be removed, myths and misconceptions can be dispelled, the reputation can improve and measurement methods can be better substantiated.

6.2.2 Recommendations for Alba Concepts
The advice for the client, Alba Concepts, is that they can reflect the above recommendations in their advice. With the knowledge of this research, they can see where the barriers lie in the transition to biobased building. Alba Concepts can also contribute to improving the reputation of biobased building materials by 'normalising' their use by promoting them and celebrating success by publicising them. They can also point out the advantages of biobased building materials such as that a wooden foundation is lighter than concrete and this leads to lower construction costs. In this way, Alba Concepts can encourage their clients to choose biobased alternatives. Alba Concepts can use tender criteria to stimulate biobased construction by not only asking for MPG as this does not make biobased building score better than traditional building. This can be done directly by asking for a percentage of biobased materials or a required/desired origin of the materials. It can be stimulated indirectly by focusing more on the residual value of a building, with biobased products being reusable and thus having a higher residual value, for instance by means of a Total Cost of Ownership (TCO).

6.3 Reflection on the process, research limitations and my process
This last heading reflects on the process and research limitations of the thesis and my process. Due to the time constraints of the study, data collection was limited to 12 interviews and 4 papers which influenced the generalizability. Since the study is of exploratory nature, this study seems to be a good step towards follow-up research. Future research could include more respondents. The interviewees are proponents of biobased building. An addition to the research would be to also interview, for example, people from the traditional building economy or lobby, or opponents. It would also be interesting to analyse newspaper articles on biobased building in addition to the papers as this supply has increased enormously in recent months. The disadvantage of open interviews is that my method of questioning affects the data retrieved. The researcher may be biased by having an opinion/view on biobased building or the researcher may be biased by output from previous interviews. Some respondents contradicted each other, it could be interesting to put them around one table through a focus group and have them spar to find out the real barriers, due to time constraints this was not possible. The research results cannot be generalised, because only a small number of people were interviewed from the whole. Also, only proponents of biobased building were interviewed and not opponents, parties from the traditional building sector. From each part of the chain, one or a few participants were interviewed while these parts are much larger. Also, for example, for the farmers, only a party responsible for the farmers was interviewed but not the farmer himself and since there was a considerable difference in 'building and developing' between the people of the practice and the experts, this may give a distorted picture. This research is only focused on the Netherlands. It may be interesting to also investigate other countries and do a comparison study in this way, the difference in approach from the government can be investigated.

According to Van Thiel (2014), the verifiability and repeatability of qualitative studies are less straightforward than for quantitative studies. Reliability is measured as the research is understandable and can be repeated. The study is reliable because the analysis is very clear and repeatable. The external validity of this study is low as only a limited number of interviews were done and documents analysed due to time constraints. This makes it unlikely that doing the exact same research will yield the same results. Partly, this is because a transition is taking place and, as a result, there are changes over time that affect the results. However, the interviewees were chosen very carefully which has a positive effect on this. The internal validity is very strong as the conclusion is very plausible under certain conditions.

Besides the research, theory and method, I also developed myself tremendously. By being disciplined and structured, I managed to bring this thesis research to a result that I am satisfied with within this time frame. I became aware of the fact that this process was a lot of 'trial and error'. Whereas at the beginning of the process, I became anxious and insecure about the uncertainty involved in this type of research, this later became a great learning point. I realise that sometimes not knowing aspects or not completing them can also be of added value, in fact, I preferred to delineate the main question even more at the beginning of the research but my supervisor advised against it. I now understand why it is better to experience the frameworks during the research in this way and leave things open as long as possible so that no important aspects were left out.

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8 Appendices

Content of appendices:
Appendix A Interview Guide Dutch
Appendix B Interview Guide English
Appendix C Interview Transcripts
Appendix D Documents of document analysis (D1, D2, D3, D4)
Appendix E Atlas.ti Analysis
Appendix F Code Book

Appendix A Interview Guide (Dutch)
Interviewnummer:
Naam interviewee:
Organisatie:
Functie:
Locatie:
Datum en tijd:

Introductie

Allereerst bedankt dat u hiervoor tijd kon vrijmaken en wilt deelnemen aan dit interview. Ik zou graag mezelf eerst voorstellen. Ik ben Jans van den Eijnde en ik studeer Spatial Planning aan de Radboud Universiteit in Nijmegen. Momenteel ben ik bezig met afstuderen vanuit de specialisatie Planning, Land and Real Estate Development bij Alba Concepts in ’s-Hertogenbosch.
Mijn onderzoek gaat over de barrières in het gebruik van biobased bouwmaterialen bij de bouw van woningen. Het doel is inzicht krijgen in deze barrières zodat dit kan leiden tot onderzoek naar oplossingen.
Door deel te nemen aan dit interview, neemt u ook deel aan het onderzoek. Vindt u het een probleem als dit interview wordt opgenomen? Ik probeer aantekeningen tijdens het interview te maken maar ik wil ook graag goed luisteren dus dan is een opname wel fijn voor achteraf. De opname kan elk moment worden stopgezet als u dit wenst. Gaat u hiermee akkoord? Dan zal ik nu de opname starten.
Wilt u in verband met privacy graag dat ik alleen uw functie noteer of mag ik ook uw naam vermelden in mijn onderzoek? De duur van dit interview bedraagt ongeveer een half uur tot één uur. Het interview kan u elk gewenst moment afbreken.

Kunt u misschien iets over uzelf vertellen?
<Sturen op de volgende aspecten: naam, leeftijd, hoogst genoten onderwijs, functie en bedrijf.>

Middenstuk

Q1. Op welke manier heeft u met biobased bouwmaterialen te maken?
Q2. Ervaart u barrières in het gebruik van biobased bouwmaterialen en zo ja, wat zijn deze zonder op detail in te gaan?
Q3. Wat zijn de **technische (praktijk) en technologische (innovatie, theorie) barrières** qua toepasbaarheid voor het gebruik van biobased bouwmaterialen?
Q4. Wat zijn **sociologische en culturele barrières** voor het gebruik van biobased bouwmaterialen?
Q5. Wat zijn **economische barrières** voor de markt in het gebruik van biobased bouwmaterialen?
Q6. Wat zijn **regulerende barrières** qua beleid en politiek voor het gebruik van biobased bouwmaterialen?
Q7. Wat zijn **regulerende barrières** qua aanbesteding en meetmethoden voor het gebruik van biobased bouwmaterialen?
Q8. Is er iets wat je nog graag wil aanvullen/vertellen naast de vragen die ik heb gesteld zoals barrières buiten deze vragen?

Afsluiting

Dan wil ik u graag nogmaals bedanken voor uw tijd en bijdrage aan mijn onderzoek. Ik hoop dat u alles hebt kunnen vertellen wat u wilde vertellen. Als laatste: stel, ik heb hierna nog een vraag, is het ok als ik u dan contacteer. Ook wil ik graag laten weten dat als u vragen of aanvullingen hebt, u me altijd mag bellen of mailen. Als u wil, zou ik het resultaat van het onderzoek over een tijdje als het af is, kunnen sturen.

Appendix B Interview Guide (English)
Interview number:
Name of interviewee:
Organisation:
Function:
Location:
Date and time:

Introduction

First of all, thank you for being able to make time for this and wanting to participate in this interview. I would like to introduce myself first. I am Jans van den Eijnde and I study Spatial Planning at Radboud University in Nijmegen. I am currently graduating from the Planning, Land and Real Estate Development specialisation at Alba Concepts in 's-Hertogenbosch.
My research is about the barriers in the use of biobased building materials in residential building. The aim is to gain insight into these barriers so that this can lead to research into solutions. By participating in this interview, you are also participating in the research. Do you mind if this interview is recorded? I try to take notes during the interview but I also like to listen carefully so then a recording is nice for afterwards. The recording can be stopped at any time if you wish. Do you agree to this? Then I will now start the recording.
For reasons of privacy, would you like me to only note your position or can I also include your name in my research? The duration of this interview is approximately half an hour to one hour. You can end the interview at any time you wish.

Could you perhaps tell us something about yourself?
<Suggest the following aspects: name, age, highest education, position and company.>

Main

Q1. In what ways do you deal with biobased building materials?
Q2. Do you experience barriers in the use of biobased building materials and if so, what are they without going into detail?
Q3. What are the technical (practical) and technological (innovation, theory) barriers in terms of applicability for using biobased building materials?
Q4. What are sociological and cultural barriers to the use of biobased building materials?
Q5. What are economic barriers to the market in the use of biobased building materials?
Q6. What are regulatory barriers in terms of policy and politics for the use of biobased building materials?
Q7. What are regulatory barriers in terms of procurement and measurement methods for the use of biobased building materials?
Q8. Is there anything you would like to add/tell in addition to the questions I have asked such as barriers beyond these questions?

Closing

Then I would like to thank you again for your time and contribution to my research. I hope you were able to tell me everything you wanted to tell me. Lastly, suppose, I have another question after this, is it ok if I contact you then. I would also like to let you know that if you have any questions or additions, you are always welcome to call or email me. If you want, I could send the result of the survey in a while when it is finished.