From Niche To Norm

An exploratory research into the opportunities of biobased building materials in the province of Gelderland

K.M.J. (Koen) Wentholt

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Colophon

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An exploratory research into the opportunities and barriers of biobased building materials in the province of Gelderland

Author:	Koen Wentholt
Student number:	s1044006
Thesis supervisor:	dr. Iulian Barba Lata
Second reader:	dr. ir. Ary Samsura
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Summary

The building sector in the Netherlands is responsible for 50% of the national raw material usage and 11% of the national CO_2 emissions. The current business as usual prospect reveals that the Dutch building sector will exceed their CO_2 budget in 2027. In addition, the Dutch house building system requires to increase their rate of production to reduce the current housing shortage. Building with biobased building materials is identified as a promising method to reduce both the current emissions and to increase the rate of production. Furthermore, building with biobased building materials reduces the omitted nitrogen of new housing developments. This is especially relevant for the province of Gelderland due to the large presence of natura 2000 areas. Housing developments within 25 kilometres of natura 2000 areas are subject to additional regulations regarding the deposition of nitrogen. This is especially relevant for housing developments in the province of Gelderland due to the presence of these large natura 2000 areas. Therefore, biobased building materials poses a promising opportunity for the province of Gelderland to reduce the CO_2 and nitrogen emissions while also increasing the rate of production.

This research aims to gain an insight into the current barriers and opportunities influencing the adoption process of biobased building materials. This has led to the following intervention question: *'How can the adoption process of biobased building materials be expedited in the house building system in the province of Gelderland?'.* The house building system in the province of Gelderland is a part of the Dutch house building system. Therefore, to research how the adoption process of biobased building materials can be expedited in the province of Gelderland it is crucial to analyse the Dutch house building system. This led to the following main research question: '*What are the current barriers and opportunities for the adoption of biobased building materials in the Dutch house building system?'* This was researched using an exploratory qualitative research design. The data gathering includes 11 respondents and 4 policy documents which where inductively and deductively coded. The interviewees where selected based on an information-oriented selection process which based on the innovation adoption process by Van Oorschot et al. (2020) and the actor network by Geels (2002).

This researched used the Multi-level perspective (Geels, 2002). This research concluded that there are several hindering and stimulating factors in the Dutch house building system. These emerged on the three analytical levels of the MLP namely the landscape, regime and niche. The hindering factors on the landscape are the different interpretation of European policy, lack of long-term unambiguous policy and in-built biases in the MPG. The stimulating factors on the landscape are creating a similar regulation environment, better enshrining policy in laws and reworking the MPG. The hindering factors on the regime level are two lock-in mechanism namely techno-economic and social cognitive lock-in. The stimulating factors on the regime encompasses two methods to reduce the influence of both lock-in mechanisms. The hindering factors on the Niche are a current stalemate hindering the development of the biobased production chain, lacking financial opportunities and expensive certifications. The stimulating factors on the niche level are the gradual development of the biobased production chain by intermediary companies, increasing the green loan programme and mapping the future demand for biobased building materials. Based on this conclusion, recommendations for practice are made which answer the intervention question.

Keywords: Biobased building materials, Gelderland, Dutch house building system, innovation adoption, Multi-Level perspective framework

Preface

Dear reader,

The Dutch house building sector faces two enormous task. The sector has to increase their rate of production while also becoming significantly more sustainable. The use of biobased building materials is a promising way to achieve the Dutch house building sector to achieve both tasks. However, the current adoption process of biobased building materials is suffering several hindering factors which explains their current low usage. Therefore, it was a logical choice to research the current hindering and stimulating factors present in the Dutch house building system.

Almost a year of research precedes the making of my master thesis: ‘From Niche To Norm’. This also marks the completion of my master Spatial Planning with specialisation Land and Real Estate Development at the Radboud University. While at times challenging, I look back on a fun and interesting time and I am proud of the end result of my research.

I would like to take this opportunity to thank my thesis supervisor dr. Iulian Barba Lata. Your guidance style allowed my to grow academically and incentivised me to go out of my academic comfort zone. I further want to thank all the interviewees who participated in this research. Without their contribution, this research would not have been able to exist. Finally, would also like to thank my friends and family who supported me during this process.

I hope you enjoy reading my master thesis.

Koen Wentholt

27-11-2024

Nijmegen

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1. Introduction

1.1 Research context

In 2023, the construction of nearly 90.000 houses in the Netherlands marked the highest number since 1999 (CBS, 2022). While impressive, this number still falls short of the targeted production of 100.000 houses annually to reduce the current housing shortage in the Netherlands (Rijksoverheid, 2024). With the current housing shortage in 2024 estimated at 401.000 homes this results in an urgent need to increase the rate of production (Ministerie van Volkshuisvesting en Ruimtelijke Ordening, 2024). Increasing the rate of production of new homes is difficult due to a shortage in construction workers, building materials, space and means of production (CBS, 2023). This is further complicated by the Green Deal in which the European Union aims to reduce their emissions by 50% in 2030 and being climate neutral by 2050 (EU, 2019). To achieve this ambitious goal, the Dutch building sector will play a crucial role. This is due to the fact that the Dutch building sector is responsible for 50% of the national raw material consumption and omits 11% of the national CO2 emissions annually (Copper 8, 2023). Figure 1 shows the business-as-usual emission scenario for the Dutch building sector. This revealed that at the current rate the CO_2 budget for the Dutch house building system will be exceeded as early as 2027.

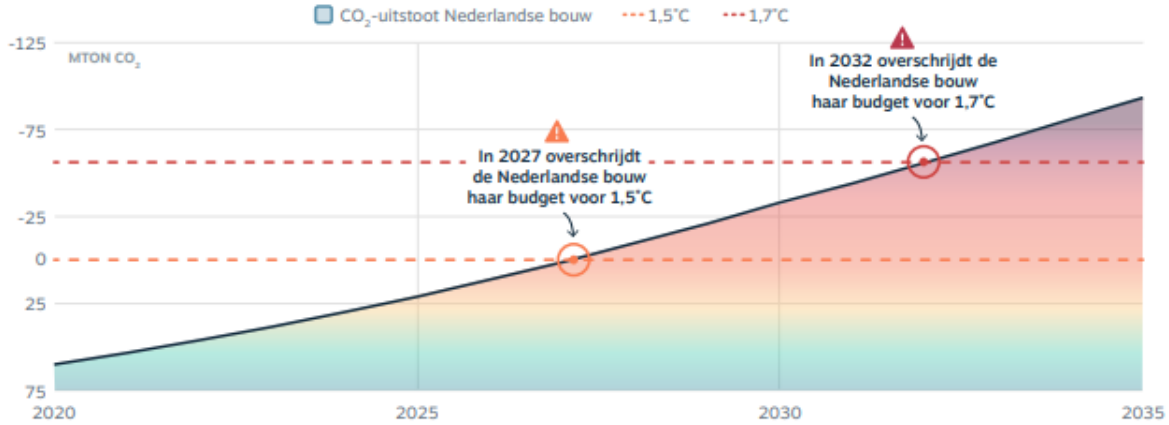

Figure 1: The business-as-usual prospect for the Dutch house building sector (Copper 8, 2023, p. 22)

This puts the Dutch house building system in a complicated situation since it requires to increase the rate of production while also significantly reducing their CO_2 emissions. Besides reducing their CO_2 emissions, the building system in the Netherlands will also require to reduce their nitrogen emissions. This is due to the fact that currently almost all Natura 2000 areas are experiencing an exceedance of nitrogen deposition which increases the decline of biodiversity (PBL, 2024; Schoukens, 2017). This led to stricter regulation for new spatial developments within 25 kilometres of Natura 2000 areas (Provincie Gelderland, 2024). This makes obtaining the additional permits for new housing developments near Natura 2000 more difficult which results in long delays and additional costs (PBL, 2024). Figure 2 (See the following page) shows the location of all Natura 2000 areas in the Netherlands as well as their current nitrogen exceedance. This map reveals the large presence of Natura 2000 areas in the Province of Gelderland, delineated with a red dotted line. As a result, the stricter regulations are enforced in a larger area within the province of Gelderland then in other provinces with less Natura 2000 areas. Therefore, the province of Gelderland has the greatest necessity to decrease the nitrogen emissions in their provincial house building system.

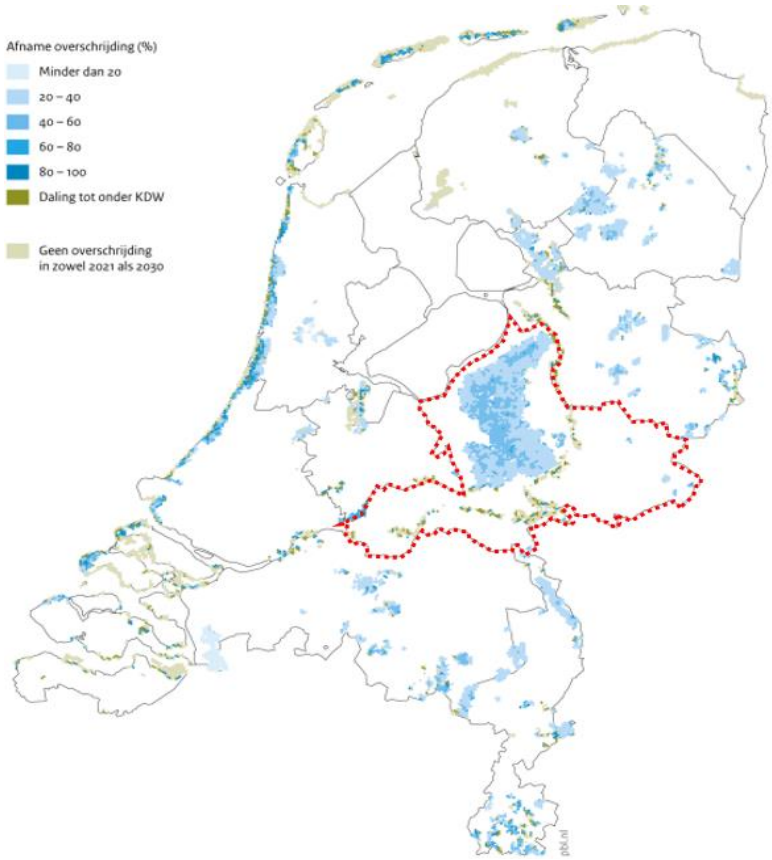

Figure 2: Nitrogen exceedance in Natura 200 areas in the Netherlands (PBL, 2024, p. 19)

A promising method to decrease both nitrogen and CO_2 emissions is replacing traditional building materials like concrete and steel with biobased alternatives. The Dutch national government gives the following definition of biobased building materials: 'Biobased building materials are materials which minimally consist of 70% renewable mass' (Rijksoverheid, 2023, p. 17). Examples of biobased building materials are isolation materials made of flax or hemp and Cross Laminated Timber (CLT). Replacing traditional building materials with biobased counterparts will significantly reduce the embodied energy when construction new homes. Embodied energy is the total energy required to for the construction, use and demolition of a building throughout it's lifespan (Yadav & Agarwal, 2021). Compared to traditional building methods, building homes with biobased building materials can reduce the building material related CO_2 emissions by 45% (van Oorschot et al., 2023). Besides significantly reducing the CO_2 emissions, biobased building materials are on average five times lighter than traditional building materials. This simplifies the building process and allows for the use of electrified and smaller construction equipment which significantly reduces the nitrogen emission on the construction site (Rijksoverheid, 2023). This proves to be especially beneficial for the provincial house building system in Gelderland since it can simplify the planning permission process to prevent delays and additional costs.

The adoption of biobased building materials within the Dutch house building system is negligible, only making up 2.1% of the total used building materials (NIBE, 2019). This is due to the rigid nature of the house building sector in the Netherlands. This rigidness derives from the fact that the house building sector is a low-tech industry. This means that the construction process is mostly standardized which limits the sector's ability to innovate the products and

the processes (Van Oorschot et al., 2020). This combined with the sector's heavy regulation results in the sector's preference towards proven concepts such as traditional building materials with steel and concrete (Dams et al., 2023). As a result, multiple barriers are in place hindering the adoption process of biobased building materials. This creates difficulties to reduce CO_2 and nitrogen emission to achieve the climate ambitions outlined in the Green Deal.

1.2 Research aim and research questions

This research aims to gain an insight into the current barriers and opportunities influencing the adoption process of biobased building materials in the Dutch house building system. This research aims to analyse these barriers and opportunities to identify factors hindering and stimulating the adoption of biobased building materials. This research also aims to gain an insight as to how the adoption process of biobased building materials in the province of Gelderland can be expedited. This research is useful to the province of Gelderland, its municipalities and private actors in Gelderland since it provides these actors with valuable information. This information can form the basis for interventions by local governments and can aid private actors to expedite the adoption of biobased building materials to reduce nitrogen and CO_2 emissions and prevent additional costs and delays. For this aim the following intervention question is formulated:

How can the adoption process of biobased building materials be expedited in the house building system in the province of Gelderland?

It is important to note that the house building system in the province of Gelderland does not stand on its own but is a part of the larger Dutch house building system. Therefore, to answer this intervention question it is important to analyse the opportunities and barriers experienced by the Dutch house building system. To achieve this the following main research question is drawn:

What are the current barriers and opportunities for the adoption of biobased building materials in the Dutch house building system?

To help formulate an answer to the main research question three sub-questions are introduced. These are formulated as follows:

1. *How are biobased building materials positioned in the current Dutch house building system?*
2. *Which factors hinder the adoption of biobased materials in the Dutch house building system?*
3. *Which factors can stimulate the adoption process of biobased building materials in the Dutch house building system?*

1.3 Scientific relevance

The European Union has labelled the building sector as a priority area to achieve the climate ambitions set in the Green Deal (Giorgi et al., 2022). This goal stimulated researchers to study the transition towards a more sustainable building sector. Van Oorschot et al. (2023) in their study, researched potential pathways to achieve a more sustainable building system in the Netherlands. This article highlighted the use of biobased building materials as being a promising method to reduce emission in the Dutch house building system. However, this research did not focus on how biobased building materials can be adopted by the Dutch house building system. Van Oorschot et al. (2020) in their research focussed on how innovation can be adopted in a house building system. They recommend that future research regarding

innovation adoption in the house building systems should be carried out with a focus on the interconnectedness of the innovation characteristics and of actors. This research aims to contribute towards this research gap by analysing the current characteristics of the innovation (biobased building materials) as well as the interconnectedness of actors within the Dutch house building system.

Research into the adoption process of biobased building materials in developed building systems is a relatively new research subject. Dams et al. (2023) researched the challenges and opportunities in the upscaling process of biobased construction. This research made a first step into making a theoretical framework for the adoption of biobased construction. However, the interviewee sample used in this research was limited in size and differentiation of interviewees sectors of work. As a result, this research did not include a respondent working in the manufacturing or installation of biobased building materials. The research by Gottlieb et al. (2023) has a larger sample size and included respondents working in the manufacturing of building materials. In their research, Gottlieb et al. (2023) recommends further research to be performed in other house building systems in other countries. Furthermore, this research was performed on a national industry level. Therefore, Gottlieb et al. (2023) recommends that future research is performed on other levels. This to shed light on the possible influences of private actors into the adoption process of biobased building materials. Gottlieb (2023) further specifies the need to look “more closely the role existing corporations play in promoting or stifling innovation” (p.10). This research encompasses the recommendations made by Dams et al. (2023) and Gottlieb et al. (2023) by analysing the adoption process of biobased building materials in the Netherlands. This with the aim to contribute information regarding the adoption process of biobased building materials in the Dutch house building system. Furthermore, his research encompasses the recommendations made by Gottlieb et al. (2023) by also analysing the adoption process on a provincial level. This research therefore contributes to the available knowledge on the influence of existing corporations and local governments have on the adoption process in their local house building systems.

1.4 Societal relevance

The EU aims to be fully climate neutral by 2050 with a 50% reduction by 2030. The house building system within member states will have to become significantly more sustainable to achieve this aim. A promising method for the house building system in the Netherlands is the adoption of more biobased building materials. This research sheds light on the rigid and complex workings of innovation adoption in the Dutch house building system. This with the aim to provide crucial insight into the current barriers and opportunities to aid the Dutch house building system to achieve the ambitions outlined in the European Green Deal. This is important since climate change has a big effect on the Netherlands due to its geographical location. Besides contributing towards achieving the ambitions set out in the Green Deal. This research is also societally relevant for the people in the Netherlands and especially in the province of Gelderland. This is due to the fact that a smooth transition of the Dutch house building system is crucial to ensure a stable an sufficient housing production (Rijksoverheid, 2023). This is especially relevant for the province of Gelderland due to the large Natura 2000 and subsequent stricter regulations in the province of Gelderland. This research contributes information to ensure a smooth transition towards biobased building materials to prevent increasing the housing shortage even further.

1.5 Reading guide

This thesis consists of 6 chapters with the first chapter stating the research context, research question and the scientific and societal relevance. The second chapter consist of a literature review and details the theoretical framework uses in this research. The third chapter outlines the methodology, data analysis, validity and reliability. Chapter 4 presents the results of this research. The sub-questions are answered in chapter 5. In chapter 6, the main research question is answered as well as the intervention question. It also contains recommendations for practice as well as a reflection of the research process and outcome.

2. Literature review and theoretical framework

In this chapter, the relevant literature and policy regarding biobased building materials and the innovation adoption in the Dutch house building system will be discussed. Thereafter, the theoretical framework will be presented and operationalised. The end of this chapter presents the conceptual model.

2.1 Literature review

2.1.1 The circular building sector

The building sector in the EU is responsible for 42% of the total energy consumption, 30% of all waste generation and 35% of all greenhouse gas emissions (GHG) emissions (Mrad & Ribeiro, 2022). These emissions are mostly related to the construction of building materials since the manufacturing of these building materials is related to 80% of the total energy consumption by the building sector (Bourbia et al., 2023). To reduce the building material related emissions, the building sector can use recycled building materials to lower the embodied energy present in buildings. The building sector in the Netherlands uses the most recycled materials of any country in the European Union with 37.9% of all building materials being of recycled origin in 2016 (CBS, 2019). There are currently two main recycling categories, one being low-end recycling and the other being high-end recycling (NIBE, 2019). Currently, the Dutch building sector mainly low-end recycles building materials for example, recycling concrete as foundation materials for highways (NIBE, 2019). This is due to the fact that traditional building materials generally posses lower potential for high-end recycling than biobased building materials (Van Oorschot et al., 2023). This is not aided by the fact that current buildings in the Netherlands are not designed to be disassembled which make the reusing of building materials in existing building more difficult and expensive (NIBE, 2019). There is an apparent lack of processing facilities which can recycle building materials in the Netherlands.

While recycling will reduce the building material emissions, reusing building materials is the preferred option according to the European waste hierarchy, see Figure 3. The characteristics of biobased building materials makes them well suited to be re-used as high-end materials (Dams et al., 2023). For example, wooden support beams can be repurposed as furniture, wooden planks, wooden flooring or as window frames (Centrum Hout, 2021). After this it can again be repurposed as other materials and ultimately be used as fuel for energy generation (Rabbat et al., 2022). Besides the higher re-usability, biobased building materials are also renewable, less energy intensive to make and store significant amounts of CO_2 (CE Delft, 2021; Hildebrandt et al., 2017; Rijksoverheid, 2023; Van Oorschot et al., 2023). Due to these characteristics, houses built with biobased building materials possess a smaller embodied energy then similar homes built with traditional building materials.

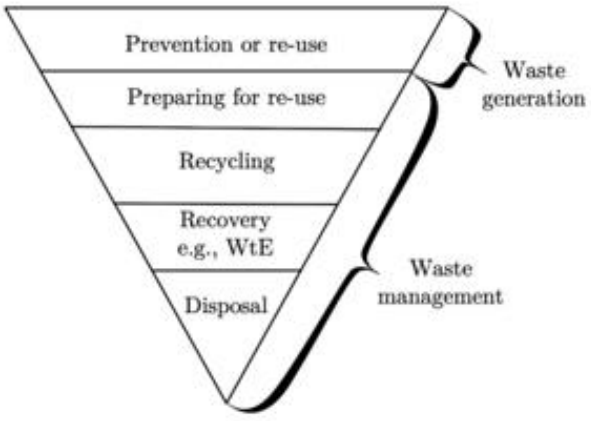

Figure 3: Waste hierarchy in the EU (Egüez, 2021, p. 10)

2.1.2 Policy background on biobased building materials

In 2023, the national government presented the 'Nationale Aanpak Biobased Bouwen (NABB)' which outlined national ambitions for the adoption of biobased building materials for the year 2030. The most significant ambition is the goal to built 30% of all homes using at least 30% biobased building materials by 2030 (Rijksoverheid, 2023). Before the introduction of the NABB, the national government already implemented multiple instruments to stimulate the building system to become more sustainable. First, there is the implementation of the 'MilieuPrestatie gebouwen (MPG)' which saw new sustainability requirements imposed on new spatial developments in the Netherlands. The MPG determines the environmental impact of a development using various environmental indicators. These indicators are derived from European norm, the EN15804 (A2) and are supplemented with Dutch applicable scenarios (NMD, 2022). The MPG also calls for the creation of a life cycle analysis (LCA) which maps the life cycle of the used building materials. After this data is verified, the MPG calculates the impact of all the indicators. This is done by predetermined calculations tools and is calculated using data stored in the national environmental database (NMD). Within the NMD database reside three distinct data classes called category 1, 2 and 3 (NMD, 2022). Category 1 data consists of proprietary which has been verified by an independent and qualified third party. Category 2 data consist of non-proprietary data. This data is then verified by an independent party. Category 1 and 2 data has been verified by the NMD and is in accordance with the NMD verification protocols. Category 3 data consist of unverified data and is owned and managed by the NMD (NMD, 2022). The data in category 3 is subject to a surcharge factor of 30%. This due to the risk of unverified data stating inaccurate environmental impacts which can result in a better rating (NMD, 2022). This calculation process of the MPG is visualised in Figure 4.

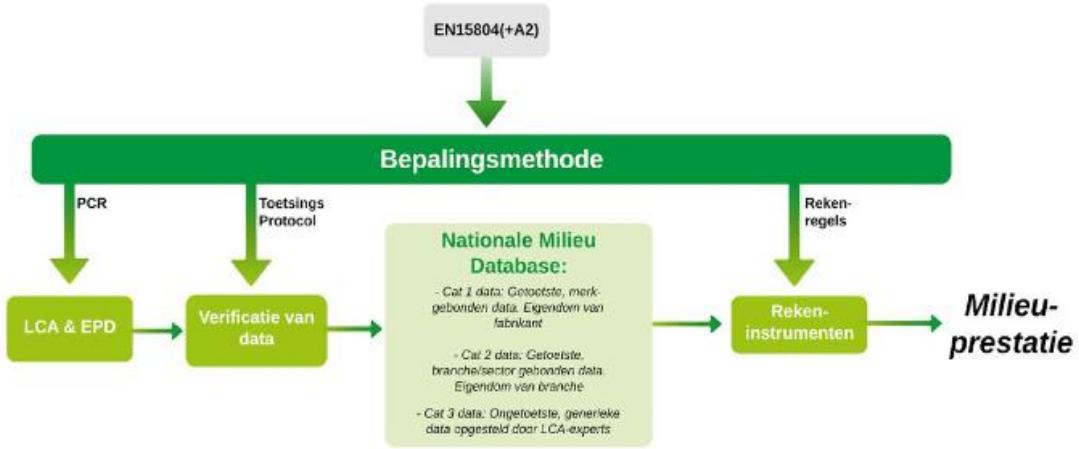

Figure 4: The current calculation method of the MPG (NMD, n.d)

Besides the MPG, the national government also stimulated market parties to use biobased building materials by providing subsidies towards the programme Building Balance. Building Balance stimulates the creation of biobased production chains to increase the supply of biobased materials. Lastly there are the 'Milieu-investeringsaftrek (MIA)' and the Willekeurige afschrijving milieu-investeringen (VAMIL) subsides in place which stimulates sustainable developments. These subsides provides financial incentives for companies and housing corporations to invest in more sustainable spatial developments (Rijksoverheid, 2023)

Besides efforts by the national government, the province of Gelderland also implements their own policies and ambitions regarding sustainable spatial development. In march 2022 the province created the policy 'Strategische Agenda Vezel-Biobgrondstoffen (SAVB)'. In this

policy document the province of Gelderland outlines, among other things, its ambitions for the high-quality use of fibre based biobased materials in the building sector (Provincie Gelderland, 2022b). The province aims to facilitate and stimulate the uptake of biobased building materials by sharing knowledge, using financial stimuli and by setting up biobased production chains and collaborations. Furthermore, it aims to bring together the supply and demand of biobased materials and to increase the awareness of biobased materials. Lastly it aims to scale up the innovations within this market by facilitating innovative companies to further develop and scale up their business processes (Provincie Gelderland, 2022b). Besides the SAVB, the province of Gelderland has also created a manual for municipalities, housing corporations and project developers called the 'Handreiking Opdrachtgeverschap Circulaire Woningconcepten'. In this policy document the province provides helpful information for municipalities, housing corporations and developers. This provincial policy document aims to increase awareness among municipalities, housing corporations and developers to integrate circular building concepts within their policies and business processes (Provincie Gelderland, 2022a).

2.1.3 Innovation in the Dutch housing system

The adoption of biobased building materials in the Dutch house building sector is dependent on the innovative abilities of the building industry. To explain the innovation adoption process it is important to point out what an innovation is. An innovation is regarded as an invention which is being implemented in the system. If the invention is not implemented it remains only an invention. In short, for it to be an innovation it has to have an economic impact in the system (Davidson, 2013). There is no shortage of new inventions in the building sector but the implementation of these inventions often falls short (Van Oorschot et al., 2020). One of the main reasons behind the lacklustre innovation adoption is due to the fragmentation of the production network and its dynamics (Van Oorschot et al., 2020). The building process is complex both technologically and organisationally (Davidson, 2013). On the organisational side, the building sector is fragmented which means that multiple actors are involved in the process like administrators, building companies, municipalities etc. This translates into what Zolghadr et al. (2022) describes as: 'a complex loosely coupled system composed of autonomous actors' (p.2). Each building project is thus a temporary cooperation between these various actors (Davidson, 2013). Given the complexity and diversity of actors involved it becomes very difficult to identify why these actors would implement new inventions in their process. Foster (1972) described this complexity as follows:

> *"Architects and engineers, for example, spend many years developing the necessary experience and expertise to perform this function [of selecting a technology] in a routine way. They learn that certain procedures work and others fail. The successful procedures are reinforced and those that fail are discarded" (Foster, 1972, cited in Davidson, 2013, p. 346).*

This dynamic described by Foster (1972) explains why the building sector often revers back to proven concepts. When it comes to the implementation of new innovations within the building sector Davidson (2013) identified two types of innovations. First there is an innovation that only involve one actor. This type of innovation does not require other actors to alter their business processes. The example given by Davidson (2013) is the implementation of Autocad. While the introduction of Autocad had a massive impact on the way architects design structures, it did not directly affect the business processes of other actors. The second type are innovations which do influence the business processes of multiple actors. This type of innovation is generally more complex since multiple actors have to alter their business process

(Davidson, 2013). This is further complicated due to the need to realign the multiple affected business processes in order to work properly with each other. When one industry business process does not align properly, all other industries will suffer negative effects. An example of this is the introduction of offsite construction (OSC). OSC generally comes with several advantages compared to traditional construction techniques such as less waste, construction nuisance and faster construction times (Zolghadr et al., 2022). Despite these advantages, OSC is to this day, still not widely adopted in the building sector upholding the notion that the housing system is complex with a lot of different stakeholders, each with their own interest. In case of OSC, certain stakeholders would benefit from its introduction while others would suffer which causes unaligned interests (Zolghadr et al., 2022).

These dynamics and tendencies results in low innovation adoption in the Dutch building sector. However, this does not mean that no innovations take place. Pries and Dorée (2005) analysed the amount and type of innovations in the Dutch building sector between 1901 and 2000. They conclude that the sector indeed innovates but that these innovations are incremental in nature. An incremental innovation is defined as a "minor change to the existing product exploiting the potential of the established design often reinforces the dominance of established firms" (Henderson & Clark, 1990, p.9). Besides incremental innovations there are also radical innovations. Radical innovations are: 'based on different engineering and scientific principles and often opens whole new markets and potential applications' (Henderson & Clark, 1990, p.9). Therefore, radical innovations tend to have a broader impact on the system where it is implemented. An example of a radical innovation is the introduction of steam powered ships. This revolutionised the shipping industry and significantly altered the workings of this sector (Geels, 2002). However, the 'radical' nature of these types of innovations makes them generally more challenging to implement in a system.

The incremental innovation nature has not changed in the building sector since the 2000s as illustrated by a study by Van Oorschot et al. (2020). In this article, 94 studies published between 1996 and 2019 regarding innovation adoption in the house building sector where studied. There were no radical innovations identified continuing the incremental nature of innovation within the house building sector (Van Oorschot et al., 2020). Van Oorschot et al. (2020) identified four main determinants which influence the adoption process of an innovation in a house building sector. These determinants are: the product's characteristics and innovation attributes, influence of the environment, industry characteristics and individual and organisational adopter characteristics (Van Oorschot et al., 2020). This means that besides the products characteristics the characteristics of the house building system described in this section and its actors play a significant role in the adoption process. Furthermore, Van Oorschot et al. (2020) emphasise the importance of the environment, which is shaped of financial opportunities, external social support, and government steering mechanisms. This conceptual framework can be found in Figure 5 (see the following page).

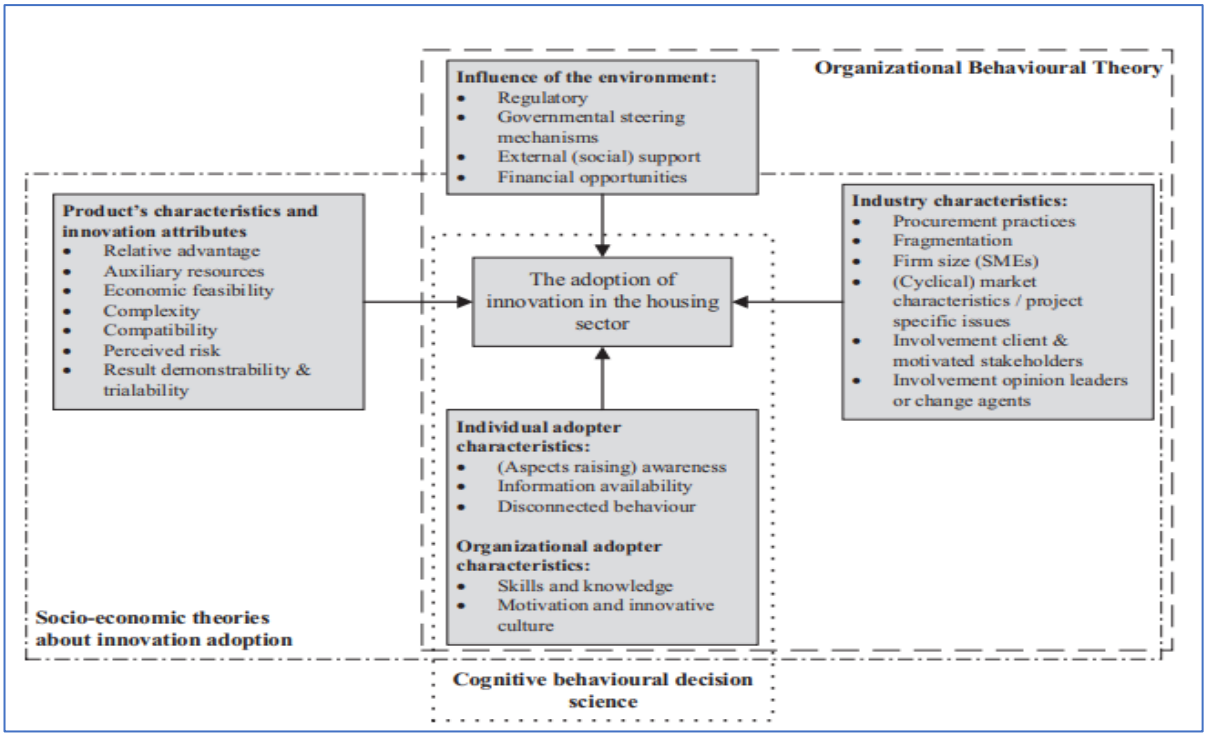

Figure 5: The conceptual framework of the innovation adoption process in the Dutch housing sector (Van Oorschot et al., 2020, p. 296)

2.2 Theoretical framework

2.2.1 The Multi-Level Perspective

The shift towards biobased building materials can be categorised as a radical innovation. It will introduce a new building material and will result in a radical change of the current house building system. It will require changes in regulations, building practices, production structures, organisational structures and creates a new market with accompanying new actors (Block et al., 2019; Setaki & van Timmeren, 2022). A transition of this magnitude is called a technological transition (Geels, 2002). A technological transformation is defined as follows:

> A *major technological transformations in the way societal functions such as transportation, communication, housing, feeding, are fulfilled. Technological transitions do not only involve technological changes, but also changes in elements such as user practices, regulation, industrial networks, infrastructure, and symbolic meaning* (Van den Ende & Kemp, 1999 as cited in Geels, 2002, p.1257).

An analysis of a technological transition is complex and requires a suitable framework. The Multi-Level Perspective (MLP) by Geels (2002) is well suited to analyse the complex process of a technological transition. The MLP framework distinguishes three hierarchical levels namely: micro, meso and macro respectively called niches, regimes, and landscapes. The niche level functions as a space where innovative activities take place and are further developed. It is a proving ground for new 'radical' innovations which, if successful, puts pressure on the regime. The regime is the network of actors and social groups, the rules (formal and informal) which are in place, and technical and material elements (El Bilali, 2019). Noteworthy is the inclusion of the social aspects of these informal and formal rules. This means that social aspects such as the roles of actors, various interests and the standards of conduct are considered when analysing the working of the regime (Pierick & Mil, 2009). The regime level in the MLP framework further highlights the interconnectedness of actor networks due to the existence of a complex set of 'semi coherent rules' (Geels, 2002, p.1260). These rules combined with the different interest of each individual actor groups and actors results in innovations with a incremental nature, often with the goal to reinforce the current practices of the regime (Henderson & Clark, 1990). Both the regime and the niche interactions resides in the landscape level. The landscape consists of "deep structural trends such as: Oil prices, economic growth, wars, emigration, broad political coalitions, cultural and normative values, and environmental values" (Geels, 2002, p. 1260). Figure 6 visualise the three levels and the influence they enact on each other. Noteworthy is the inclusion of the government in the shaping of the landscape. This is exemplified by an analysis by Geels (2002) which noted the significant impact governmental legislation had in stimulating the innovation adoption in the shipping industry in the 18th and 19th century. While changes do occur on the landscape level, it is generally understood that these changes happen slower than on other levels.

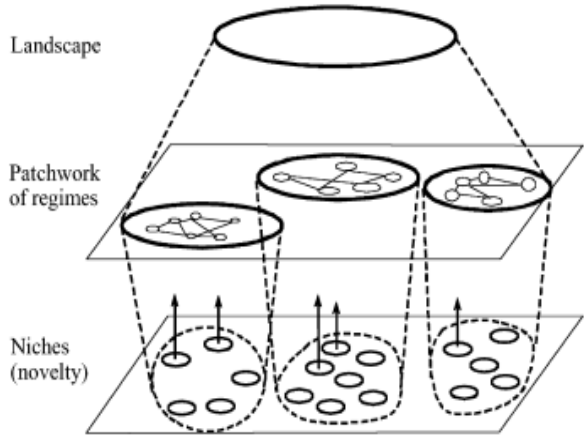

Figure 6: The three hierarchal levels of the MLP framework (Geels, 2002, p. 1261)

While the MLP framework is suitable to analyse a technological transition, it is not without its criticism. Critics of the MLP framework highlight the fact that the definitions used in the MLP framework are too abstract (Pierick & Mil, 2009). An example of this is the (lack) of definition of the three analytical levels, the landscape, regime and niche. While this framework provides the researcher with an abstract definition of what the three levels entail. It does not provide an exhaustive list of elements which should be incorporated in the analysis (Pierick & Mil, 2009). In order to operationalize these concepts the researcher is required to fill in the blanks on certain aspects of the framework. Geels (2011) explains that the lack of delineation of these concepts make them applicable to: 'empirical topics of different scopes' (p. 31). However, Genus & Cole (2008) note that this lack of delineation results in the MLP framework reliance on choices and deliberations made by the researcher to define these concepts (Genus & Coles, 2008). This is significant because this also results in the reliance of the MLP framework on the researcher to distinguish what aspects will be incorporated into the research as well as the order of importance of these aspects (Genus & Coles, 2008; Pierick & Mil, 2009). This can cause the researcher to overlook certain aspects which can prove critical for the analysis (Pierick & Mil, 2009). This subjectivity raises concerns about the replicability of an analysis using the MLP framework. To reduce the influence of the subjectivity of the researcher, Genus & Coles (2008) recommend that the researcher sufficiently explain their research choices and interpretations. These choices include the selection of cases and the collection and attribution of information (Genus & Coles, 2008). Geels (2011) agrees and suggests that: 'the analyst should first demarcate her object of analysis and then operationalise the analytical levels from the MLP' (p. 31). The significant influence of the choices and deliberation on the outcome of this research is noted. Therefore, in compliance with the recommendations of Genus and Cole (2008) and Geels (2011) the three analytical levels will be operationalised later in this chapter.

Furthermore, the MLP has been criticised to inadequately incorporate the influence of agency (Genus & Coles, 2008; Smith et al., 2005). Smith et al. (2005) defines agency as follows: 'agency in the transformation of socio-technical regimes is the ability to intervene and alter the balance of selection pressures or adaptive capacity' (p. 1503). Geels (2011) explains that agency is a critical component of the MLP framework due to interaction of the niche and the regime where power and agency certainly plays a role. However, Geels (2011) also argues that certain types of agency are less developed in the MLP framework. This research takes note of this limitation and therefore, the role of agency and power will be critically examined. Lastly, the MLP received criticism due to its bias towards bottom-up change models (Geels, 2019, 2011). Geels (2011) agrees that earlier research may have overemphasised the bottom-up dynamics and neglect ongoing processes on the regime and landscape level. To counter this bias, this research will, in compliance with the recommendation made by Geels (2011) pay more explicit attention towards the existing processes and dynamics on the regime and landscape level.

2.2.2 Landscape

The landscape of the housing system is the context in which the system works. It consists of multiple actors and can initiate a change or a continuation of the current regime (Geels, 2002). Therefore, the landscape is a critical level to examine. The landscape enacts two main functions in the transition process namely putting pressure on the regime to change and to create (favourable) opportunities for niches (El Bilali, 2019). The role of politics enact a significant role in executing these two functions. This political role is divided into multiple levels. The Netherlands, being an EU member state, is subject to European policy and legislation. This influences the national government which is required to aligns the national

policy with that of the EU. This is illustrated by the plans by the national government to become fully circular before 2050 which is based on the European Green Deal. The Dutch national political system consists of three levels namely national, provincial and municipal. The national level is regarded as the most influential since the state is a central player in the establishment of basic institutional, structure, property rights, regulatory changes, and rules of exchange which influence the actor behaviour in the regime (Vermeulen et al., 2007). The national governments ability to impact the changing of building regulations and legislation is of significant importance since the likeliness of adoption increases when suited legislation and regulations are in place (Dams et al., 2023; Dewick & Miozzo, 2002; Gottlieb et al., 2023; Van Oorschot et al., 2020). These changes can create beneficial circumstances for the niche and put pressure on the current regime. However, it is important to note that the influence of the state is not limitless. Powerful corporate actors can limit the effectiveness of government interventions (Vermeulen et al., 2007). Powerful corporate actors such as professional associations and interest groups can namely influence the policies adopted by the national government. An example of this significant influence it the failed transition of the concrete industry in the Netherlands (Vermeulen et al., 2007). A significant factor attributed towards this failure was the governments commitment towards a policy of participation. This participation meant dealing with large firms, representative trade and professional associations. This allowed these actors to shape policies and this in turn resulted in an in-built bias favouring the status quo (Vermeulen et al., 2007).

In addition to the national governments' ability to change policy, the national government is also regarded as the principal educator and disseminator of information to the market (Dewick & Miozzo, 2002). Furthermore, the national government can also function as a launching customer and demonstrate the usability and promise of new innovations with demonstration projects (Rijksoverheid, 2023). Figure 7 shows an example of a demonstration project namely the 'Rijkskantoor de Knoop' located in the city of Utrecht. This pilot project was used to stimulate the use of biobased building materials by demonstrating the opportunities of biobased construction methods. Besides demonstration project, the national government can also impose a significant impact on a transition by creating a guiding vision (Smith et al., 2005). A national guiding vision can influence the behaviour of actors since it provides: 'a stable frame for target-setting and monitoring progress' (Smith et al., 2005, p. 1506). A guiding vision generally provides an alternative possibility for a social problem and can, in combination with a predetermined target set by the government, influence the capital and resource allocations of actors in a system (Smith et al., 2005). For example, a guiding vision backed by the national government or an influential financial institution will have a greater chance of gathering support. However, the gaining of support is also heavily depended on the credibility of the backing organisation (Smith et al., 2005).

Figure 7: The biobased interior situated of the 'Rijkskantoor de Knoop' (Twee Snoeken Architectuur, n.d.)

The national legislation and policies shape the provincial and municipal legislation and policies. However, it is important to note that provinces and municipalities enjoy large shares of autonomy. National legislation often leave room for the individual provinces and

municipalities to shape it to their provincial/municipal needs. Furthermore, the provinces and the municipalities can implement their own policies and legislations for their respective regions. This results in the fact that provinces and to a larger extent municipalities can alter the landscape characteristics of their respective regions. Besides the political influence there is also the external (social) support This is categorised by financial opportunities, governmental support and client demand (Van Oorschot et al., 2020). The financial opportunities are an important factor since large upfront investments are usually required to develop an innovation (Van Oorschot et al., 2020). Furthermore, the political sensitivity of implementing direct economic instruments in a country are also emphasized (Dewick & Miozzo, 2002). This can shift over time with political shifts in a county. Lastly there are other external factors not directly linked to an actor group but are known variables which are susceptible to unexpected change and speculations. These factors are oil and energy prices, the economic situation in a country, the geopolitical situation and the availability of traditional building materials (El Bilali, 2019). Long-term changes in these factors can result in behavioural changes of actors in the current regime.

2.2.3 Regime

The regime in the MLP framework plays a significant role whether a technological transition will take place. Kemp et al. (2001) expresses this importance since: *'it is the alignment of developments (successful processes within the niche reinforced by changes at regime level and at the level of the sociotechnical landscape) which determine if a regime shift will occur'* (p.277). The regime in this technological transition is defined as the current Dutch house building system and consists of multiple actor networks and social groups. These different actor networks and socials groups are interconnected and display various actor interaction dynamics as well as the existence of formal and informal rules. Geels (2002) visualised the actor network and its interconnectedness, this actor network can be found in Figure 8.

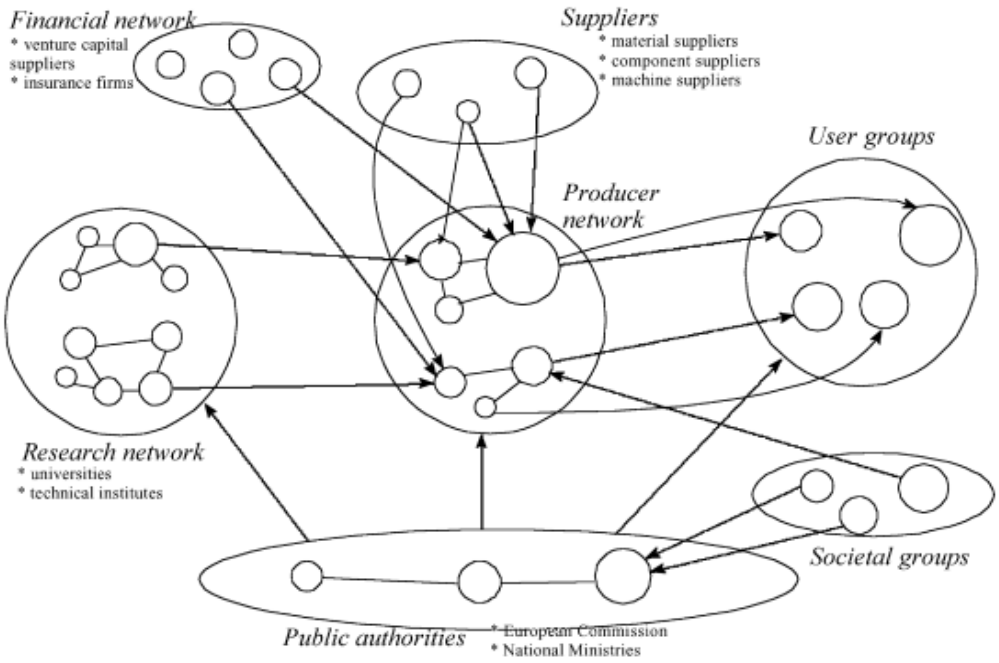

Figure 8: Actor network of the regime (Geels, 2002, p. 1260)

The actor network by Geels (2002) display multiple actor groups within an actor network namely: the financial network, research network, producer network, public authorities, societal groups, users groups and suppliers. As outlined in paragraph 2.1.4, the Dutch house building sector is fragmented and consists of a system devised of autonomous actors distributed in multiple actor networks. The actors in the Dutch house building system posses different interests, preferences, strategies and resources. This results in each actor behaving differently to achieve their aims to improve their position. This dynamic is what Grin et al. (2010) calls an 'aggregate game process' (p. 46). Geels (2004) elaborates the following on the workings of this dynamic:

> *In each round actors make "moves," i.e. they do something, e.g. make investment decisions about R&D directions, introduce new technologies in the market, develop new regulations, propose new scientific hypotheses. These actions maintain or change aspects of ST-systems. The dynamic is game-like because actors react to each other's moves. These games may be within groups, e.g. firms who play strategic games between each other to gain competitive advantage. There may also be games between groups, e.g. between an industry and public authorities (Geels, 2004, p. 909).*

The aggregate game process described by Geels (2004) emphasises the influence of the interconnectedness of the various actors and actor networks, this is also visualised by the various arrows displayed in Figure 8. The aggregate game process generally results in a relatively stable environment with a predictable trajectory sometimes also known as path dependency (Geels, 2004; Grin et al., 2010). This path dependency is also displayed by the Dutch house building system due to the focus on incremental innovations which generally reinforce the status quo (Pries & Dorée, 2005). This path dependency is reinforced in the Dutch house building system due to the existence of multiple lock in mechanisms at play. First there are the two distinct techno economic lock in mechanisms namely sunk investments and the favourable characteristics of the current technology. The current Dutch house building system has made significant investments to improve their business processes. The introduction of a new innovation negates these improvements of their business process which results in high sunk costs (Atkinson et al., 2014; Geels, 2019). This makes the traditional building regime reluctant to invest or transition to different business processes reinforced by the fact that they are still yielding benefits from the current building system (Atkinson et al., 2014).

The second techno economic lock-in regards the characteristics of the existing technologies. These are often regarded as low cost and high performance (Geels, 2019). This is logically explained due to their long term usage as well as decades of incremental innovations (Geels, 2019; Gottlieb et al., 2023). Biobased building materials, being a relatively new addition to the modern house building system, lack the innovations and gained knowledge compared to traditional building materials (Dams et al., 2023). This increases their initial costs and makes building companies hesitant to adopt biobased building materials (Dams et al., 2023; Gottlieb et al., 2023). Furthermore, there is a high risk associated with introducing new innovations or a technology in the building sector. This raises concerns among building companies to adopt biobased building materials due to uncertainties regarding the profitability, performance and quality of these materials (Dams et al., 2023; Gottlieb et al., 2023). This is not aided by the fact that traditional building materials enjoy significant economies of scale (Geels, 2019). This enables companies to spread out large investments through a larger output which results in lower unit prices of traditional building materials (Atkinson et al., 2014).

The second lock-in mechanism regard the social and cognitive aspects present in the Dutch house building system. These lock in mechanisms are defined as: 'the routines and shared mindsets that 'blind actors' to developments outside their focus' (Geels, 2019, p.189). This is reinforced by the social capital produced by the alignment between social groups and the user practices and life styles which revolve around certain technologies. Traditional building materials have been the norm in the current Dutch house building system for multiple decades. This results in a lack of technical knowledge surrounding the design, manufacturing and installation of these new biobased building materials (Gottlieb et al., 2023; Williams & Dair, 2007). Biobased building materials also generally experience a negative public perception (Gottlieb et al., 2023). Users often prefer the 'solid' concrete and steel construction as opposed to the 'fragile' wooden construction practices (Gottlieb et al., 2023). Lastly, there is an institutional and political lock-in mechanism at play. On the one hand this regards the existing regulations, standards and policy networks on the landscape level which reinforce the existing status quo and creates an uneven playing field (Atkinson et al., 2014; Dams et al., 2023; Geels, 2019; Gottlieb et al., 2023; Hurmekoski et al., 2015). Furthermore, the often large vested interest make their way into policy networks to 'water down regulatory changes and hinder radical innovations' (Geels, 2019, p. 189).

2.2.4 Niche

A technological transition is also dependent on the development of the niche. The niche functions as an innovation space where innovations can take place and develop. The MLP framework suggest four phases in which the development of the niche and subsequent technological transition can reside. These four phases are visualized in Figure 9.

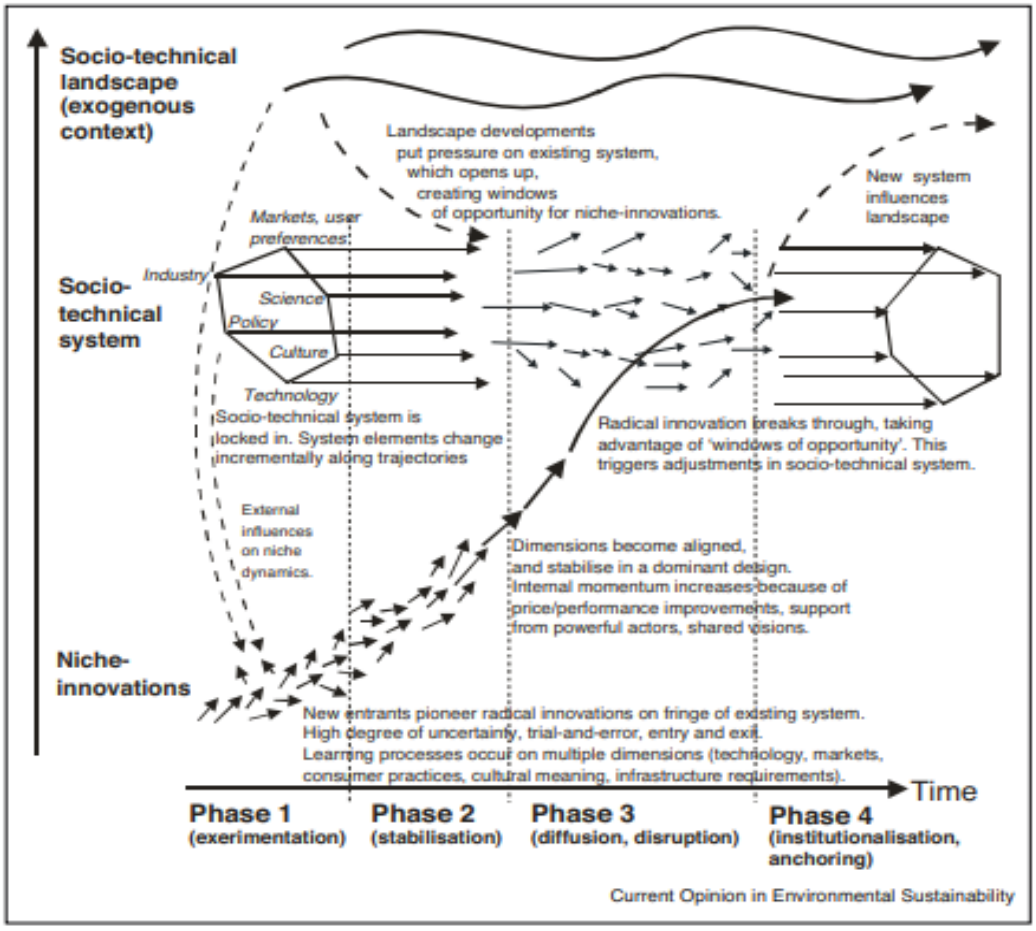

Figure 9: Multi level perspective on socio-technical transitions (Geels, 2019, p. 191)

Biobased building materials, like al niches, started in the 1st phase. This phase is categorized by extensive testing and improving the niche innovation. This 'experimentation phase' allows actors to quickly learn valuable information and to establish first concepts or business cases (Geels, 2019). In the second phase, 'the innovation enters small market niches that provide resources for further development and specialization.' (Geels, 2017, p. 465). As a result, the innovation rises as a promising business venture however, is still accompanied with significant risks and relatively low demand. (Geels et al., 2017). In this phase, the innovation also aims to gather more technical knowledge and design guidelines (Geels, 2019). The add on of the niche to the established regime, also known as hybridisation, is often found at the forefront of widespread diffusion (Geels, 2002). In the third phase, landscape developments as well as the maturing and further development of the niche innovation creates a window of opportunity to pressure the regime to change. The third phase also consists of improving the economies of scale, increasing the price/performance of the niche and to gather support from important actors (Geels et al., 2017). The fourth phase means the institutionalization and means that the niche has solidified its position within the regime albeit replacing the entire or a part of the old regime (Geels et al., 2017). This phase usually entails the innovations to be embedded within regulations and production networks.

The development and subsequent increased influence of a niche to a regime is further visualized in Figure 10. This dynamic shows that while the niche matures, the window of opportunity allows it to expand its market share and increase the importance in the existing regime ultimately causing a regime shift (Schot & Geels, 2008). Furthermore, the niche dynamic shows that a regime change does not occur overnight but is a process which can take multiple years or decades.

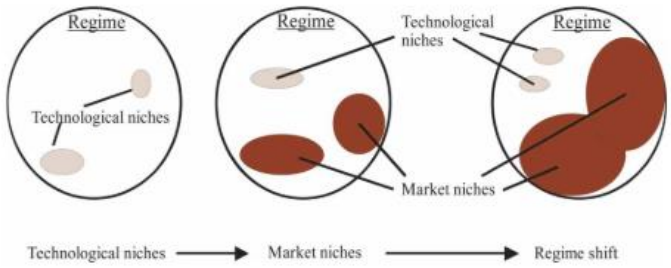

Figure 10: Niche dynamics to a regime shift (Schot & Geels, 2008, p. 540)

While the Netherlands is generally regarded as one of the front runners in the transition towards a circular economy (Marino & Pariso, 2020; Mazur-Wierzbicka, 2021). The uptake of biobased building materials within the building sector remains almost negligible (CE Delft, 2021; Dams et al., 2023; Rijksoverheid, 2023). The current use of building materials in the Dutch building system is visualised in Figure 11.

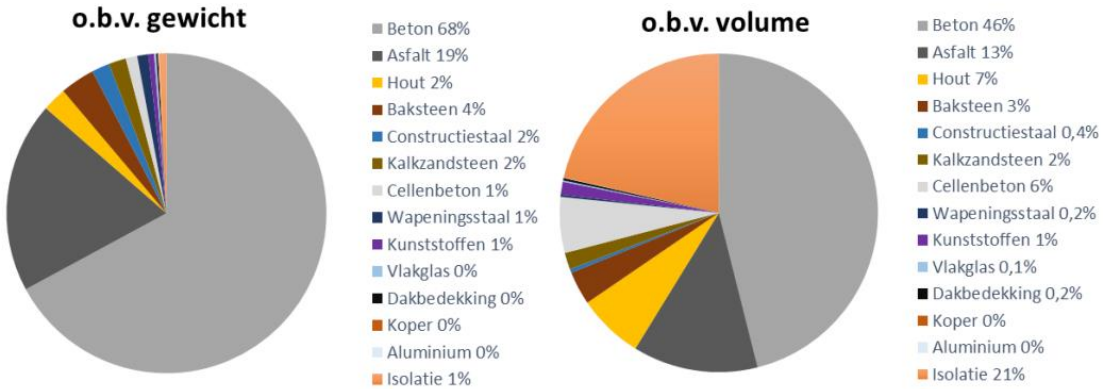

Figure 11: The shares of used building materials in the Dutch construction sector by weight (left) and price (right) (Nibe, 2019, p. 8)

The current usage of biobased building materials in 2019 based on weight in the Netherlands is 2.1% (NIBE, 2019). It should be noted that the main used biobased material is wood which was responsible for 2% of the total used biobased building materials. This means that all other biobased building materials such as hemp, flax only has a share of 0.1% in the current building system (NIBE, 2019). However, while these are the most recent figures, the maturing of the biobased niche has come a long way. Office buildings, social housing, schools, hotels and a train station have all been built using biobased building materials (CE Delft, 2021). Furthermore, large firms such as BAM and Heijmans are opening the first factories focussed on constructing houses using biobased building materials (BAM, 2021; Heijmans, 2023). It is important to note that not all biobased building materials are equally developed. For example, façades and foundations made with biobased building materials are generally underdeveloped. While main support structures and insulation materials made from biobased building materials are relatively further developed (Rijksoverheid, 2020). This provides main support structures and insulation materials made from biobased materials with better product characteristics which positively influences their adoption process in the current Dutch house building system (Van Oorschot et al., 2020).

Besides the development of the individual biobased building materials lies the development of the supporting industries. These supporting industries consist of the agricultural industry and the processing industry and are generally underdeveloped, especially compared to the supporting industries of traditional building materials (Dams et al., 2023; Rijksoverheid, 2023). Dams et al. (2023) note the importance of developing the supporting industries of biobased building materials. This is due to the fact that this will increase their availability which increases their potential to be used on a wider scale. The biobased building materials production chain in the Netherlands is visualised in Figure 12.

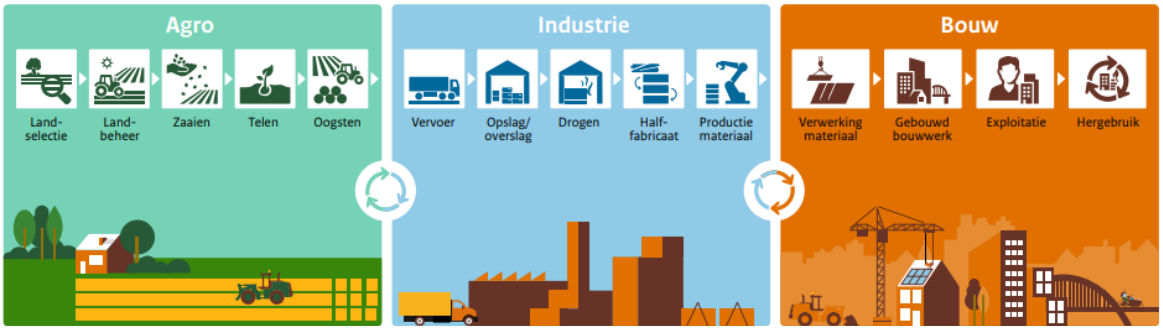

Figure 12: The biobased production chain in the Netherlands (Rijksoverheid, 2023, p. 13)

To develop a stable biobased production chain it is crucial that all three parts of the chain are developed simultaneously (Rijksoverheid, 2023). Otherwise there is a risk that considerable discrepancies will arise between the supply and demand of biobased building materials which can significantly hinder the adoption process (Dams et al., 2023; Gottlieb et al., 2023). The agricultural industry cultivating crops dedicated to the manufacturing of biobased building materials in the Netherlands is small and consists of just 2000 hectares in 2023 (Rijksoverheid, 2023). The main factor contributing to this small supply is due to profitability concerns cultivating biobased materials (Dams et al., 2023; Rijksoverheid, 2023). In addition, the Netherlands lacks an established processing industry like industrial sawmills and other biobased material processing industries (Rijksoverheid, 2020). This creation of processing industries to manufacturer biobased building materials requires significant up-front investments. This in turn creates a difficult business climate for smaller companies to enter

and generally favours larger companies with more substantial financial capabilities (Gottlieb et al., 2023).

2.2.5 Conceptual model

The operationalisation of the three analytical levels revealed multiple barriers hindering the adoption process of biobased building materials in the Dutch house building system. However, the operationalisation also revealed several opportunities that can expedite this adoption process. This is visualised in a conceptual model which can be found in Figure 13.

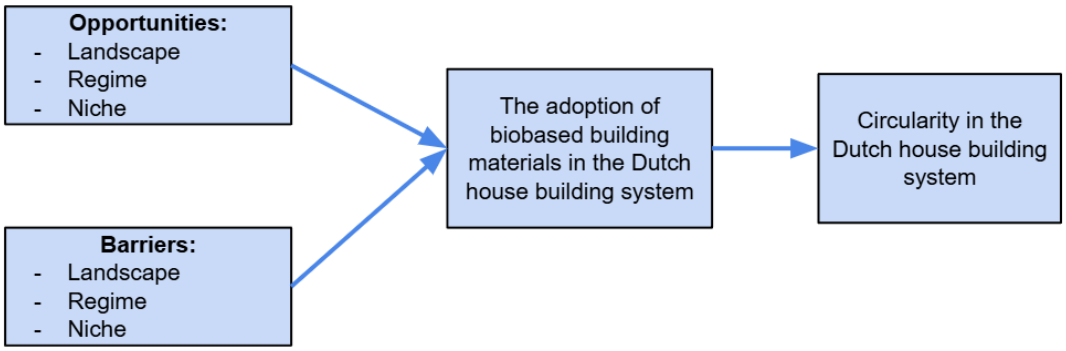

Figure 13: Conceptual model

3. Methodology

In this chapter the methodology of the research is outlined. This entails the methods used to select interviewees and the gathering of the data and analysed policy documents. At the end of this chapter, the reliability and validity of this research will be elaborated.

3.1 Research strategy

The adoption process of biobased building materials in the Dutch house building system has not been researched previously hence an exploratory research was chosen. This research is inductive which, according to Van Thiel (2014), is a suitable research method for sectors which lack the existence of ample scientific literature. This research used a qualitative research methodology. This is due to the complexity of innovation adoption in the Dutch house building system. Qualitative research is well suited for this research since its design compliments the researches aim to analyse a complex system with multiple interconnected variables (Cypress, 2015). This method further allows the researcher to gradually shape the research which is beneficial to encompassing every aspect of the complex system like the Dutch house building system (Vennix, 2016).

3.2 Research methods

Significant information regarding the innovation process of biobased building materials was not available beforehand. This provided difficulties setting up a sound research methodology since parts of the system where unknown beforehand. Therefore, prior to the start of the research, three pilot interviews were conducted with actors within the Dutch (biobased) house building system. These interviews shed light on underexposed elements and provided valuable insights regarding the current institutional and market developments in the Netherlands. This was crucial since literature regarding these developments in the Netherlands did not exist. These interviews, while using the same interview guide, where designed to be informal in nature. While some interview questions where composed, the purpose of the pilot was to start a discussion to distil the important areas of the Dutch (biobased) house building system where research is scarce and thus relevant to explore. The interviews where conducted in Dutch and lasted between 15 and 30 minutes. The interviewees are shown in table 1. The pilot interviews provided an in depth insight into the complexity of the system and helped demarcate the research subject.

Organisation	**Name interviewee**	**Function**	**Date**
Klok Groep	Thijs Pleijhuis	Manager sustainability	24-1-2024
Hollands Houtland	Sandra Nap	Director Holland Houtland	29-1-2024
Alba Concepts	Djordy van Laar	Senior consultant	2-2-2024

Table 1: List of pilot interviewees

The research was conducted through a qualitative analysis. This analysis consisted of desk research, policy document analysis, and the primary data was gathered through interviews

3.3 Primary data collection

3.3.1 Interviewee selection

The adoption process of biobased building materials affects all actors in the current Dutch house building system. This is relevant for the interviewee selection since it influenced which interviewees are relevant to incorporate in this research. CE Delft (2021) provided a clear overview of all actors present in the biobased building process. This overview can be found in Figure 14.

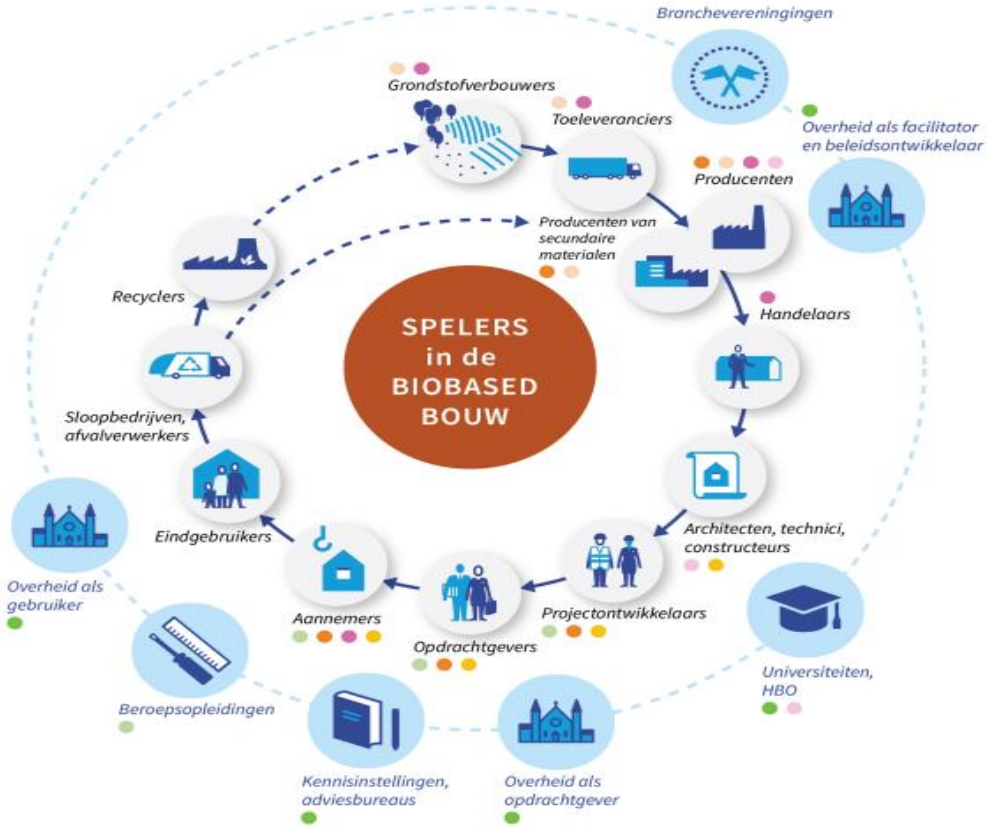

Figure 14: Actors in the biobased building process (CE Delft, 2021, p. 27)

This overview includes actors from all three analytical levels. However, the focus of this research lies on the adoption process of biobased building materials. As a result, it was important to focus on the actors which play a role in this adoption process. The innovation adoption framework by Van Oorschot (2020) provides a framework to determine which actors play a role in this process and should thus be includes in this research. This framework was used in conjunction with the actor network by Geels (2002) to verify the selection of relevant actors in the Dutch house building system. The innovation adoption process by Van Oorschot et al. (2020) as well as the actor network by Geels (2002) are listed on separated pages respectively listed as Figure 5 on page 17 and figure 8 on page 21.

Using this method, a proper selection of actors can be diffused from the CE Delft (2021). The experienced reality by different actors further highlights the importance of selecting relevant actors. In line with earlier research regarding the adoption process of biobased building materials by Dams et al. (2023) and Gottlieb et al. (2023) participants with first-hand experience with biobased building projects were selected. This selection process is called information-oriented selection and is suitable to maximize information gathering from relatively

small samples (Flyvbjerg, 2006). To examine the house building system 11 relevant actors were interviewed, these are listed in table 2. This strategy, including the sample size, has been used in earlier research by Dams et al. (2023) and Gottlieb et al. (2018).

	Organisation	Name interviewee	Function	Date	Duration (Min)
1	GreenInclusive and Building Balance	Loraine Westerneng	Region manager & communication manager at Building Balance and MT-Member at Greeninclusive	20-9-2024	46
2	GewoonHout	Bram Bevers	Manager costumers and market	26-6-2024	48
3	Orga Architecten	Guus Degen	Projectarchitect	10-6-2024	56
4	Klok Group	Thijs Pleijhuis	Manager sustainability	28-5-2024	37
5	Province of Gelderland	Myriam van Zetten & Huibert Verdoold	Projectmanager circular economy (Myriam) and Advisor Wonen (Huibert)	8-7-2024	57
6	Ministery of BZK	Bouwe Meijer	Policy officer Biobased Building	16-8-2024	40
7	Rabo smart builds	Rikkert Besselse & Geert Dirkse	Business analyst Construction and circularity (Geert Dirkse) and Business development manager (Rikkert Besselse)	30-8-2024	42
8	Heijmans	Francis Velthuizen	Designmanager	18-7-2024	50
9	Portaal	Vincent van Huijgevoort	Advisor sustainability, circularity and climate adaptation	19-6-2024	57
10	Staatsbosbeheer (Hollands Hout)	Kasper Broek	Product development manager	3-6-2024	46
11	Groenemetropoolregio Arnhem-Nijmegen	Robert Mullink	Driver and program manager	21-8-2024	68

Table 2: List of selected interviewees and general information

3.3.2 The interviews

Due to the exploratory nature of this research, a semi-structured interview was chosen. This is a suitable method to gather data when little literature is available beforehand and further allows the researcher to ask follow-up questions based on the answers given during the interviews (Bryman, 2012). These follow-up questions provided a more in-depth analysis into the adoption process of biobased building materials in the Dutch house building system. One interview guide was used to enhance the reliability of the research. This interview guide is listed in appendix 2. All interviews where conducted in Dutch since this was the native language of the interviewees and the researcher. This prevented translation errors and allowed interviewees to convey their answers without a possible language barrier. The interviews were conducted in the period between May till the end of September. The operationalisation of the Dutch house building regime revealed that the behaviour of the actors influences the functioning of the system. Furthermore, there is a discrepancy in the possessed agency by actors within the system. Therefore, the ontology and epistemology of this research are outlined. The different realities experienced by the different actors mean that the ontology of this research is relativism (Moon & Blackman, 2014). This way, we can review the different realities experienced by the different actors. Focussing on the differences between these realities allows the answering of the research question. The epistemology of this research is

subjectivism since the behaviour of different actors pose a significant impact on the system. The system cannot be researched without the actual actors present that function within it (Moon & Blackman, 2014).

3.3.3 Policy review

The influence of National and local policies on the landscape warranted the analysis of relevant policy documents to gain a deeper understanding of the policy background. These documents where derived from suggestions made during the interviews. These are listed in Table 3.

	Document name	Author	Published year
1	Nationale aanpak biobased bouwen	Ministerie van binnenlandse zaken	2023
2	Het Nieuwe Normaal 1.0	Cirkelstad	2023
3	Actieplan Wonen 2020 - 2025	Provincie Gelderland	2020
4	Convenant Duurzame Woningbouw	Provincie Utrecht	2022

Table 3: List of policy documents

3.4 Data analysis

The audio of the interviews was recorded and transcribed to provide a complete overview and to prevent that important aspects where not included in the research. To provide a clear transcription for the analyses, repeated words where removed. Also, grammatical mistakes where corrected only if it did not effect the meaning of the answer given by the interviewee. This provided an edited transcription of the 11 conducted interviews which where analysed using the coding program Atlas.ti. Atlas.ti allows the researcher to systematically analyse the data which improves the reliability of the analysis since all transcripts where analysed in the same way. The policy documents derived from the interviews where also coded in Atlas.ti. The coding of certain parts of the transcripts and policy documents 'serve as shorthand devices to label, separate, compile, and organize data' (Charmaz, 1983, as cited in Bryman, 2012, p.568). The analysis of the data was done using both deductive and inductive codes. The deductive codes were derived from the scientific literature and where structured in three analytical levels based on the MLP framework. This makes the division of the three analytical levels possible as well as to give the researcher a more detailed view of the misalignments present in certain parts of the system. However, the complexity of the system combined with insignificant previous scientific publications results in the need to also include deductive codes. This allows the researcher to incorporate new information which may not have been found in previous research. This resulted in multiple rounds of coding where trial and error gradually led to the refinement of the codebook. This led to the creation of a code book including both deductive and inductive codes. This coding process places significant responsibility in the hands of the researcher to think creatively and logically (Van Thiel, 2014). The pilot interviews conducted before the start of this research highlighted the interconnectedness of the Dutch house building system. Therefore, the gathered data was coded using an axial coding method. This allows the researcher to analyse the 'contexts, conditions, interactions, and outcomes of a process' (Gupta, 2024, p. 106). This in turn can explain 'if, when, how, and why something occurs' (Gupta, 2024). The axial coding method allowed the researcher to better analyse the social aspects and subsequent game aggregate game process present in the current Dutch house building system.

3.5 Reliability and validity

According to Van Thiel (2014), the reliability and validity of qualitative research is less straightforward compared to quantitative research. As a result, to refer to the reliability and validity of qualitative research term such as the repeatability, transferability and plausibility are used (Van Thiel, 2014). The reliability of the research is dependent on the accurate and consistent measuring of variables (Bryman, 2012). The consistency of this research was improved by using one interview guide for every interview. This ensured that every respondent provided their an answer to all interview questions. Furthermore, the use of semi-structured interviews increased the accuracy of this research since it allowed for follow-up question which allowed the researcher to extract more in-depth information. This research used deductive codes derived from previous literature on technological transitions and the adoption of biobased building materials. However, previous literature is limited and therefore this research also used inductive coding. This allowed the researcher to analyse new possible linkages influencing the adoption of biobased building materials in the Netherlands which may not have been found in previous literature. The use of an axial coding method increased this research ability and thus accuracy to gain an insight into the social interactions and interconnectedness of actors effecting the adoption process. This systematic coding process increases the repeatability and thus reliability of this research (Bryman, 2012; Van Thiel, 2014).

The exploratory nature of this research limited the ability to confirm the results in previous literature. The plausibility of this research is improved by a thorough interviewee selection process. The interviewees where selected using an extensive literature analysis on the adoption process of innovations within the Dutch house building system. This is supplemented with three pilot interviews which provided a well-informed selection process which increased the plausibility of this research. To increase the plausibility of the research it is important to include a sufficient amount of respondents (Van Thiel, 2014). This research, based on recommendations by previous research, included a larger sample size (11 interviewees) which improves the internal validity of this research.

4. Results

In this chapter the results of the analysis of the information gathered in the interviews and policy documents are discussed. This chapter is structured based on the three analytical levels of the theoretical framework namely landscape, regime, niche. Table 4 provides a summary of the interviews and policy documents. Furthermore, the table shows how the interviewees and policy documents are referred to in the text.

nr	Organisation	Interviewee function	Reference in text
1	Klok Groep	Manager sustainability	R1
2	Staatsbosbeheer	Product development manager	R2
3	Orga architecten	Projectarchitect	R3
4	Portaal	Advisor sustainability, circularity and climate adaptation	R4
5	GeWOONhout	Manager costumers and market	R5
6	Heijmans	Designmanager	R6
7	Province Gelderland	Projectmanager circular economy (Myriam) and Advisor Wonen (Huibert)	R7
8	Ministery of BZK	Policy officer biobased building methods	R8
9	Groene Metropoolregio	Driver and program manager	R9
10	Rabosmartbuilds	Business analyst Construction and circularity (Geert Dirkse) and Business development manager (Rikkert Besselse)	R10
11	Green Inclusive	Region manager & communication manager at Building Balance and MT-Member at Greeninclusive	R11
nr	**Policy Name**	**Author**	
1	Het Nieuwe Normaal 1.0	Cirkelstad	P1
2	Nationale Aanpak Biobased Bouwen	Ministerie van binnenlandse zaken	P2
3	Actieplan Wonen 2020 - 2025	Provincie Gelderland	P3
4	Convenant Duurzame Woningbouw	Provincie Utrecht	P4

Table 4: Overview of interviewees and policy documents and their respective reference

4.1 Landscape

4.1.1 European Union

The respondents highlight the actions that the national government make directly dictate their actions and their chances of success. However, the actions that the national government make are heavily dictated by the European Union (R8, R3). Nevertheless, the Dutch government does have a certain amount of leeway in integrating the European policies and agreements into their national policy. This autonomy resulted a unique interpretation of the European legislation compared to other member states such as France of Germany (R3, R7, R8, R9, R11). An example of this is the integration of EN15804 regarding the new Environmental Product Declaration (EPD) norms. The Dutch national government, different to neighbouring

countries, integrated all sustainability indicators, including the indicative indicators within the Dutch policy (R8). This complicated the integration of new foreign biobased building materials into the Dutch building system since the certifications that apply in other member states do not necessarily apply in the Netherlands (R3, R7 R11). This is deemed problematic by multiple respondents since it makes it difficult to integrate other biobased building materials in the Dutch building system (R7, R9, R11). It also negatively influences the ability to respond to sudden changes in the supply and demand for biobased building materials since the market is mostly dependent on the Dutch building sector (R3, R7). This makes it more difficult to invest in the biobased sector due to the fact that if the Dutch house building sector stalls, it will most likely results in an almost total loss of demand (R7).

4.1.2 The Dutch national government

lack of long-term policy

All respondents mention the significant influence the national government possesses to influence the landscape with new policies and laws which can alter the behaviour of actors within the current Dutch house building system. Several respondents highlight the importance of long-term unambiguous policy (R1, R6, R7, R8, R10, R11). This long-term policy is deemed vital to provide clarity to the house building system what the future governmental ambitions entail and to provide a time frame to schedule investment. A respondent mentioned the fact that France has these goals set out till 2031 which aids companies to plan their investments and gives them clarity for the long term as to what rules/ambitions their company has to comply with (R8). Multiple respondents indicate that the absence of these goals/ambitions in the Netherlands have significant negative effects on the transition to a circular building sector (R1, R7, R8, R10 R11). This is due to the fact that it increases the risks of investments since it is not known whether these investments will provide returns (P2). There is a chance that the path chosen by a building company differs than that of the national government which is a significant problem since it makes building companies hesitant to invest in biobased ventures (R1, R7, R10, R11, P2). Written in the NABB itself is the notion that the current interventions listed in the policy are subject to change and can be disregarded al together (P2). As a result, the confidence in the longevity of ‘long term’ goals set by the national government is low (R10). This is due to recent events regarding the ‘salderingsregeling’ of solar panels and the withdrawal of the mandatory instalment of a hybrid heat pump by the national government. These events made companies manufacturing hybrid heat pump drop their prices and reduced their projected returns of their investments (R10).

The MPG

Multiple respondents raise their concerns about the details regarding the data and the calculation methods of the MPG. These concerns are separated in the data side and the calculation side. The concerns about the data side concern the NMD database which functions as the database for the MPG calculations. Multiple respondents have voiced concerns regarding the so called ‘data 3’ class since it disproportionally targets new mostly biobased building materials (R1, R3 R5). This is due to the way the NMD classifies data which is cumbersome and expensive which makes it difficult for new, mainly biobased, building materials to get the proper data classifications (R1, R3, R5, R7). Subsequently, this results that information about new, mainly biobased, building materials are placed in the ‘data 3’ category. Within this category there is a 30% uncertainty tax which negatively effects the sustainability outcomes for materials in the data classification (R1, R3, R5). Therefore, it is

said that the expansion of the NMD database is vital to make the calculations of the MPG more realistic (R1, R3) Multiple respondents find it important that the national government aids the creation of data to be used in the NMD to level the playing field and give sustainable building materials a fair change (R1, R5, R10). This will also result in better investment opportunities and more opportunities for the niche to develop (R1, R6, R10).

Besides concerns about the data side of the MPG, there are also concerns regarding the calculation methods used in the MPG (R1, R3, R5). Respondents note that the current end-use scenarios in the MPG differ from what can be realistically expected (R1, R5). For example, the current end-use for wood is incineration for the purpose of energy generation. This gives wood a disadvantage in the calculation methods since this end-use scenario does not take the positive effects of cascading wooden building materials into account (R1, R3 R5). Secondly, the current MPG does not take carbon storage into account (P1). This negatively impacts biobased building materials since they generally store significant amounts of carbon (P1). The levelling of these disparities can significantly boost investment opportunities since biobased building materials will be judged on their actual characteristics and thus become more competitive (R1, R5).

Furthermore, respondents mention the frequent changing and adaptations within the MPG policy (R1, R6). This makes it difficult for companies to comply since it is unknown how the situation will look like when it changes again (R6). This results in multiple construction companies choosing safety and therefore, not to invest in innovative sustainable building materials like biobased due to these regular policy changes (R6, R7). Besides concerns regarding the effects of often changing the details in the MPG. Multiple respondents also note that the tightening of the MPG ambitions is happening too slowly (R1, R10). It is argued that the tightening of the MPG is a significant factor in the uptake of biobased building materials (R1, R5, R6, R7,). The slow tightening results in the fact that unsustainable building methods can still compete with its sustainable counterparts (R4, R5). However, respondents also note the fine line of tightening the MPG regulations (R8, R9). This is due to the fact that a mistake in this tightening process can disqualify significant parts of the Dutch building sector which can lead to bankruptcies as well as a reduction in construction capabilities (R8). To aid in this process multiple respondents mention the fact that the national government should ask companies what can be realistically expected to gain an insight as to how the MPG can be tightened (R5). To further aid in this process the government aims to set up an ambition guide line within the MPG. These stricter requirements are not legally enforced but rather serves as a crucial insight for building companies as to what the future tightening of the MPG will entail. Similar to long-term unambiguous goals in policies, this can aid construction companies into their investment- and sustainability strategies (R8).

Subsidies

Two respondents and the NABB both mention the positive influence subsidies have on stimulating the use of biobased building materials (R3, R6, P2). These subsidies namely artificially improve the business case of biobased building projects by decreasing the costs (R3, R6, P2). While subsidies does improve the business case, the effectiveness is questioned since the business case without the subsidies would not be balanced (R4, R7). Therefore, subsidies only improve the business case when they are in effect. To improve the actual business case as a whole the national government, besides subsidising biobased building projects, also provided a 200 million euro subsidy to for the creation of biobased production

chains (R8, P2). However, a respondent questioned the effectiveness of this subsidy since other factors first have to be improved before these biobased production chains can operate effectively. An example that was given was expending the knowledge of biobased building materials in the NMD database to level the playing field with traditional counterparts (R9).

4.1.3 The unique position of the province and the municipality in the landscape

The national government is dependent on the provinces and the municipalities to enforce their policies. However, the province and municipalities posses the authority to impose more ambitious regulations concerning the circularity of new spatial developments (R1). This allows provinces and to a larger extent municipalities to exert influence on the landscape in their respective regions (R1, R3, R7, R8, R11). However, municipalities are dependent on the construction companies to built sufficient housing in their respective region (R2, R4, R7). The provinces are in turn dependent on the municipalities to achieve their construction quota's as well as the sustainability ambitions (R8). Therefore, while the provinces and municipalities can expert some influence in shaping the landscape in their respective regions. This requires delicate deliberation since, similar to the national government, implementing overly ambitious regulations can have a negative effect on the rate of construction of new housing (R1, R3, R9). Which considering the current housing shortage is deemed undesirable.

4.1.4 Other landscape factors

A respondent mentioned the current housing shortage and subsequent high housing prices as a negatively impacting the willingness of actors to adopt biobased building materials (R1). Companies are concerned that the usage of new, relatively untested biobased building materials can increase the already high prices. Furthermore, a respondent mentioned the preference of the public to traditional brick and mortar housing (R6). While this preference is decreasing gradually, it would aid if the there was a greater emphasis on the necessity of using more biobased building materials (R6). An example of this was the public opinion of chopping down trees in Dutch forests. This is seen as the destruction of nature despite the fact that most forest areas in the Netherlands actually benefit from the extraction of wood, if this is done by FSC guidelines (R2). The national government can aid the public support by providing information regarding the positive influence using biobased building materials have on reducing emissions. Besides the public, two respondents mention that changing the attitudes towards biobased building materials of leading can positively influence the adoption process (R2, R7). This is due to the fact that the leading firms in the Netherlands posses the means and scale to significantly influence the current house building system in the Netherlands (R2).

4.2 Regime

4.2.1 Financial network

Respondents note that there is a keen interest of financial actors in biobased initiatives (R5, R6). However, financial actors are generally focussed on biobased initiatives by biobased companies backed by larger parent companies (R5). These initiatives offer less risk due to the backing of large parent companies with significant financial resources (R6). It was noted that these preferences are logically explained due to the reduced risks accompanied by these investments (R8). It is reasoned that the financial actors are generally less socially committed than public actors due to the increased focus on recouping their return on investments (R1, R8). In general, financial actors are passive and watch the biobased economy developments closely to see how the business case is evolving (R8). Investment companies namely benefit from investing in these industries later when the business case has evolved (R1, R9).

Furthermore, there is a need for new investment models for biobased developments due to their higher residual value and higher initial costs (R1, R2, R3). Multiple respondents mention the role the insurance companies (R1, R2, R3, R4, R5). The exact influence of the usage of biobased materials regarding insurance coverage and fees is not exactly clear (R1, R3, R4). A respondent expects an additional fee due to uncertain certifications of biobased building materials (R1). However, other respondents have not noticed a different approach by insurance companies (R3, R4, R5).

4.2.2 Supplier network

The supply network consists of multiple actors including the cultivation of biobased materials and the usage of these biobased materials. Multiple respondents express their concerns about the availability of biobased materials like fibre crops and wood (R1, R2, R3, R7, P2). Furthermore, multiple respondents mentioned the distinct lack of knowledge surrounding these biobased materials. These knowledge gaps concern the consistency of the materials, fire resistant properties, noise characteristics and the longevity of the materials (R1, R6). While the national government aims to stimulate the creation of this knowledge (P2). There is a current lack of sufficient technical knowledge of biobased building materials. Two respondents note the significance of this lack of knowledge by emphasising the vast impact changing a traditional building materials with a biobased counterparts has on the business process (R1, R6). The materials used in the construction process are namely not easily interchangeable (R1, R6). First, the different, mostly unknown, characteristics of biobased materials provide risks since it is unknown how the material will react over time which can make a company liable should there be defects detected down the line (R6). A change in the used building materials also warrants the need for new tests regarding fire safety and noise compliance by building companies (R6). These tests are cumbersome and expensive since the tests require building companies to completely re-test their products in the end-use (R6).

After retesting, the next step is to determine how the new material fits in the current production process. This is of significant importance since the production process is designed in a certain way and deviating from this process will require a business wide change (R1, R6). The example given is using new biobased insulation building materials. The testing regarding the installation process of this new biobased insulation material is expensive and is the responsibility of the manufacturer (R6). However, this test is crucial since it provides the manufacturer with technical information such as the time if takes to install biobased insulation materials. This is crucial since the current production process is mainly determined by the installation time required in each step (R6). If the new biobased material takes longer to install then the traditional material it replaces, it affects the entire production process (R1, R6). Introducing a completely new production process is complicated and costs significant amounts of time and financial resources (R6). Furthermore, it is also unknown if the current machinery present in the factory is suitable to work with these new materials. This requires additional testing by the manufacturer regarding the exact properties of these new biobased materials. The testing of these properties is time-extensive and may result in the need for the retooling of factories (R6). It is also mentioned that, due to the novelty of the innovation, suitable machinery to apply these new materials may not yet exist (R6). These factors result in high financial investments required to replace traditional building materials with a biobased counterpart. As a result, this induced resistance the current supplier network to adopt biobased materials (R6).

Besides the development of integrating biobased materials into the manufacturing process in the supplier network resides the development of traditional building materials. Companies manufacturing traditional materials such as steel and concrete are introducing innovation to make traditional materials more sustainable (R3, R5, R6). An example that was given is the use of green aggregates when manufacturing concrete (R6). This development takes place by the current regime to make the current process more sustainable in order to stay competitive (R5, R6). Respondents mention that these innovations combined with favourable assumption in the MPG results in the fact that these materials remain competitive to biobased building materials. (R1, R2, R3, R4, R5, R6). Furthermore, it was noted that these traditional materials have been integrated in the construction sector for many decades (R1, R6, R7). Therefore, there is an extensive technical body of technical knowledge available of these materials present in the current house building system. Furthermore, traditional building materials are generally more consistent which is a favourable property which is not yet established for the biobased counterparts (R7).

4.2.3 Research network

A respondent mentioned the historic lack of attention for biobased construction methods within the research network (R3). However, in recent years universities and higher learning institutions are working hard to gain more insights and are teaching new building methods, like biobased, to new students (R3). This knowledge will take some time to take into effect since it has to make their way into the existing house building system (R3). Furthermore, a respondent noted that the consultancy firms regarding biobased initiatives, sometime seen as a precursor to a database, also don't have all the information available at the time of writing (R6). This illustrates the current lack of available technical knowledge regarding biobased building materials which negatively influences the adoption of these materials.

4.2.4 User groups

A respondent notes the historic lack of demand for biobased building materials (R6). Consequently, this resulted in a distinct lack of experience among user groups (R9). This results in the fact that user groups, which will work with these biobased materials, are unfamiliar with the characteristics of said materials and also have no network to obtain these materials (R6, R8). The characteristics and methods of construction where traditionally gathered in ‘SBR details now called ISSO details’ (R6). These documents provide information about the applications, characteristics and provide recommendations when using different materials (R6). These documents are not yet available for biobased building materials which hinders the usage by the user groups. In addition, there is a lack of knowledge as the where these various biobased building materials can be acquired (R6). It requires the establishment of a new user network with new suppliers and venders which increases the costs related to the use of biobased building materials (R6).

4.2.5 Producer network

Two respondents mention the inherent nature of the producer network to remain invested in their current building practice (R1, R7). This is due to the security and less associated risk it provides (R1). The changing of the building practice is not restricted by purely switching building materials, it also entails changing the way buildings are assembled and the methods of exploitation and investment methods (R1, R2, R3). Furthermore, the use of biobased materials also requires additional factors to take into account such as the yield of the harvest (R11). This knowledge is not required when using traditional building materials and as a result the existing knowledge of new factors is limited (R3). The gathering of this knowledge is

cumbersome and usually requires companies to obtain firsthand experience since actors within this process are reluctant to share information about their practices (R6). Obtaining this knowledge is not stimulated due to the current lack of incentive to use these new biobased materials. This is due to the fact that the MPG norms can still be achieved using mainly traditional building materials (R3, R4). This lack of incentive accompanied with the greater associated risk with these new biobased materials result in a lack of necessity from companies in the producer network to adopt these materials (R7). Respondents also mention the frequent changing assumptions present in the MPG (R1, R6). This makes it riskier to opt for a certain biobased building materials now since the pace, the assumptions and the direction of policy are not known (R1). This fact, combined with the large up front investments indulges companies to wait and analyse how the policy and business case is evolving before making their investment choices (R1). However, it is known within the producer network that there will become a point when, to comply with the tightening MPG regulations, the use of biobased building materials will be required (R9). The exact implementation speed of this process is not known which incentivises companies to wait and analyse the developments to gain more security as to when to invest and in what biobased business ventures (R6).

4.2.6 Societal group

Multiple respondents note the influence the lobby of traditional building materials on the construction sector (R6, R7, R8, R9, R10). The traditional lobby groups have large invested interests and there have been instances where these interests have shaped policy (R6). However, two respondents also note the importance of these interests when dictating new policies (R7, R8). Lobby groups namely represent a significant part of the Dutch house building system and can provide crucial information to help the national government to create feasible policies. This is due to the fact that when policies are too ambitious, it can disqualify a significant part of the house building system (R8). However, the significant vested interests that are at play should be noted when working with lobby groups (R8, R9).

4.2.7 Public authorities

Municipalities

Multiple respondents mentioned the level of knowledge possessed by municipalities surrounding biobased building materials is limited, this was also noted in existing policies (R1, R4, R7, R9, P2, P3). This is especially prevalent in smaller municipalities (R1, R11). This posses a challenge since municipalities are dependent on private actors to built sufficient housing in their regions. This is cause for a delicate deliberation by municipalities whether to add additional ambitions within their policy and projects (R7). This is due to the fact that additional ambitions almost always take their toll on the business case (R8, R9). Too ambitious municipal ambitions can cause delays. An example that was given is the ‘Woontoren Duet’ in Nijmegen. The municipality implemented additional circularity ambitions in the bidding process. After the bidding was awarded, it became clear that the current plan was not economically feasible due to these additional circularity ambitions which has led to the delay of the project (R9). Furthermore, the various ambitions are not the same in each municipality which make it difficult for construction companies since they have to adjust their building practices in each municipality (R1, R5. R9, R10). Also, the committees within the municipalities judging the aesthetics of new developments are also hesitant to approve plans which use biobased building materials due to their different appearances (R6, R19). However, important to note is that this attitude is changing since this fact is disproved by another respondent (R10).

Respondents also mention the long and cumbersome planning system in the Netherlands (R1, R7, R9). These planning processes are usually responsible for the longest period in a spatial development (R1, R7). While respondents argue that these processes are important, (R7) it is also noted that these processes cause significant delays (R9). The largest factor in expediating housing construction is attributed to the approval of land-use plans with the construction process being a relatively smaller factor (R1, R7). An example of this is the usage of appeals to purposefully delay developments for long periods of time (R7, R9). This can strain the economic feasibility of developments due to possible future increases in labour and material costs (R7, R9). A possible solution proposed is increasing the participation of local residents (R7).

Provinces

Multiple actors mention the role of the province in expediating spatial developments (R1, R4, R5, R7, R8, R9, R10, R11). A provincial instrument to achieve this is the use of a 'provinciaal inpassingsplan' (R1, R5). This instrument is seen as a method to increase the amount of development sites within a province (R1, R5, R7). Furthermore, it is also proposed that the province should embed above standard circularity ambitions to these additional development sites (R5). However, adding additional circularity ambitions can further complicate matters for house building companies (R1, R5). Also, a direct provincial intervention is unlikely since it is politically sensitive to do so since it directly impedes the authority of the municipalities (R7). However, the province of Gelderland is actively supporting municipalities to accelerate housing developments (P3). This supports entails the assistance of gaining (nitrogen) permits, personnel support, simplifying provincial procedures and providing information about new sustainable building processes (P3). Another instrument is the role the province enacts in shaping the agricultural sector. Multiple actors mention the fact that province can use this instrument to transition the agricultural sector by executing a stimulating policy towards fibre crops to be used by the biobased building industry (R1, R8, R10, R11, P2). However, it should be noted that the province has more ambitions to take into account such as the stimulation of biodiversity, supporting small businessowners and food production (R7). Also, a respondent mentioned the fact that the supply of biobased materials cannot be used when there are no sale guarantees for these biobased materials (R9). Furthermore, the importance of providing a proper business climate for the processing industry to settle was noted (R11). Possible interventions to achieve a better business climate are: subsidies, power connections and also increasing demand for biobased building materials (R9, R11).

4.3 Niche

4.3.1 The agricultural industry

Noted in multiple interviews and the national policy is the current lack of biobased materials production such as fibre crops and wood in the Netherlands (R2, R7, P2). Currently there is only a small area, roughly 2000 hectares, dedicated to growing fibre crops (P2). This is significantly less then the national policy's aim of 50.000 hectares by 2030 (P2). Also, a respondent noted that the current wood production in the Netherlands is declining (R2). Normal wood production in the Netherlands is estimated to be around one million cubic meters. The most recent estimates however put this number at only 850.000 cubic meters (R2). Most wood production happens in other countries such as Germany and Finland. This fact in addition to the longer growth times of trees results in the focus on the cultivation of fibre crops (P2). The cultivation of fibre crops is for most farmers not the main source of income since it usually only makes up a small percentage of the farmers total land (R7). This is mainly due to the lack of profitability in the business case of many fibre crops (P2). Besides the

profitability, many farmers are concerned about the long-term business case of fibre crops (P2). The national government aims to reduce these risks by formulating additional policy regarding the cultivation of fibre crops (P2). However, while additional policy can help. A respondent emphasised the importance of sale guarantees for farmers cultivating fibre crops and the currently difficult to obtain such sale guarantees (R11). This results in the following chicken and the egg dynamic, according to multiple respondents (R8, R11). The agricultural industry need sales guarantees for their products since the risk to switch to fibre crops is too great without them (R8, R11). However, the processing industry is reluctant to provide these sale guarantees since it would require them to set up a processing factory without an existing and tested supply chain (R6, R8, R11). Building Balance is working on reducing this dynamic however, a respondent questioned the effectiveness of these efforts (R9). This is due to the fact that the scale of these efforts is too unsignificant (R9).

4.3.2 The processing industry

The processing industry is also experiencing a chicken/egg dynamic similar to the agricultural industry (R11, P2). The processing industry requires sale guarantees by the producer network because otherwise they will be investing significant funds without any direct sale guarantees (P2). The producer network however, is hesitant to provide these sale guarantees due to availability concerns (P2). Furthermore, the lack of an economically viable business case will result in a higher cost when using these biobased building materials (R1). This makes the housing corporations and municipalities hesitant to enforce above MPG standards ambitions due to concerns that this may cause delays (R11). This hinders the scale-up of manufacturing capabilities of the processing industry and agricultural industry due to the limited demand imposed by this dynamic (R7, R8, R11). This results in a stalemate which is not aided by the need for the producer network to set up a new network of suppliers (R6). This networking takes time since new experiences have to be created between various different companies (R6). Respondents mention that, despite the lack of national policy, there are certain steps that can be undertaken to reduce the multiple chicken/egg dynamics (R6, R11). The example being the creation of a company which functions as a intermediary between the farmers, the processing industry and the construction industry (R11). These intermediary companies can provide all three industries with long standing sale guarantees which can reduce the current stalemate (R6, R11). An example of said intermediary was the creation of a fibre corporation in the province of Brabant. Multiple housing corporation mapped their future biobased insulation materials needs which provided the processing industry and agricultural industry with a crucial insight into future demand (R10). This reduces the current chicken/egg dynamic since this offers a perspective for both supporting industries to develop (R10). Besides sale guarantees, the processing industry also expresses their need for new NEN norms regarding biobased building materials. These norms specify the expectations of products as well as produce new suitable test methods for biobased building materials (R6, R8). These norms are being development but due to the new characteristics of biobased building materials this will take more time (R8).

4.3.3 The building industry

Respondents mention the current lack of incentive experienced by the building industry to use biobased building materials (R1, R7, P2). While the current lack of incentive does affect the demand for biobased building materials. Respondents mention the fact that larger firms are experimenting with their own biobased concept since it is generally known a change in the system will come in the future (R1, R2, R3, R9). However, actors are currently reserved to use biobased building materials due to concerns regarding the availability, characteristics, and

certification surrounding these new biobased building materials (R3, R4, R8). This results in the building industry reluctance to agree to sale guarantees of biobased building materials produced by the processing industry. Furthermore, these concerns results in a high-risk for building companies to switch their current traditional building process to a biobased building process. Multiple respondents mention that a gradual introduction of biobased building materials into their current building process can significantly improve their sustainability while reducing the accompanied risks for building companies (R1, R7, R8, R10, R11). This method is introduces a new hybrid construction form which uses both traditional and biobased building materials. This hybrid form allows for gradual integration of biobased building materials by for example swapping traditional insulation materials with biobased counterparts (R11). Another example is the replacing traditionally made walls, ceilings and façades by biobased counterparts made by Hollands Hout. The hybrid construction method is promising since it greatly reduces the CO_2 emissions related the used building materials (R1, R7, R10, R11).

Another method to reduce the financial risks by building companies is the use of biobased building materials when constructing flex dwellings (R10). Flex dwellings due to their temporary nature also enjoy a lighter planning permission process (R10, P3). The average planning permission of a flex dwelling is between the 10-15 years (R10). As a result, flex dwellings are a useful method to temporarily reduce a shortage of homes in a municipality (R10). Furthermore, after the flex dwelling is built and occupied the municipality can also decide to transform the temporary permit into a permanent permit. This is beneficial since the longer permanent planning permission process can take place while the flex dwelling is already housing occupants (R10). Their temporary nature may result in the need for relocating flex dwellings to a different location. The favourable detachability characteristics of biobased building materials reduces the costs of this relocation (R8, R11).

The important role of housing corporations is also emphasised since they are in possession of large amounts of real estate and can function as launching customers (R4, R11). However, these corporations are faced with a dilemma. On the one hand, housing corporation are ambitious and aim to increase their circularity (R5). On the other hand, they are faced with the reality of these decisions. These are namely that the initial investments are higher in combination with uncertainty surrounding the certifications and longevity of these building materials (R4). This is not aided by agreements made between the government and the housing corporations to set goals for the construction of sufficient social housing (R4). Housing corporations have a certain amount of capital to invest and the current higher prices of biobased building materials will inevitably result in the fact that fewer social dwellings can be constructed (R1, R4). This is important since a choice in more sustainable and thus more expensive social housing can endanger their obligations to the national government to construct enough social dwellings (R4). It is noted that housing corporations are interested to use these materials however the means they possess are not endless (R8, R11). It is further noted that there have been instances of resistance towards biobased social housing developments due to the fact that people are reluctant to live in these dwellings (R4). This is especially relevant since housing corporation are bound to the so called 70% rule (R4). This means that any development which changes the rent should gain 70% support by the owners. This is more relevant when retrofitting social housing and social housing renewal projects and less with newly built dwellings (R4).

4.3.4 Financial opportunities

The financial opportunities enacts a significant impact on the niche (R2, R7, R10, R11). Multiple respondents note the difficult introduction of new biobased building materials in the biobased building materials market (R2, R7, R10, R11). This is due to the large up-front investments required when setting up a biobased building material company (R2, R7, R10, R11). Furthermore, respondents mention that due to the higher associated risks, companies entering the biobased building material market are forced to arrange their own financing arrangements (R1, R9, R10). The main factors for these high initial costs are low demand, lack of economies of scale and the costs of certifications (R1, R2, R3, R5, R6, R7, R8, R11). The implementation of the hybrid construction form and flex dwellings both increase the demand for biobased building materials which can stimulate the further development (R1, R5, R7, R8). Certification is necessary to increase the trust in these materials as well as being able to sell them in the Netherlands. This is not aided by the fact the Netherlands has their own certification scheme which result in the fact that biobased building materials with European certification are subject to recertification (R9, R11). Also, respondents mention the fact that the lack of initial financing options result in the fact that only larger companies, often backed by their parent company, can introduce themself in the market (R1, R2, R3, R4, R5, R6). Respondents also mention that, besides dealing with certifications, there is also the added costs of providing additional data to the NMD (R4, R5). This data gathering for the NMD is essential since it removes the uncertainty tax for these biobased materials which increases their competitiveness (R3, R5, R9). It is noted by respondents that these high investments limit smaller companies to introduce themselves in this market (R3, R6). However, the national government is collaborating with financial actors to provide green loans which offer lower interest rates (R1, R3). Respondents emphasise the effectiveness of these green loans since they have a significant impact on the business case (R1, R3). Despite this impact, respondents also mention that the improved economic feasibility due to these green loans does not entirely compensate for the higher initial investments (R1, R3). Furthermore, a respondent mentioned the significance of the large networks of financial actors such as banks (R10). These networks can be used to create more awareness among actors as well as to boost the confidence of the opportunities of the niche (R10).

4.3.5 Provinces

Multiple respondents mentioned the creation of a covenant within the province, municipalities and private actors (R8, R9). An example of a covenant that was mentioned by a respondent was the ‘Convenant Duurzame Woningbouw’ (R8). In this document, the province of Utrecht, municipalities, and market parties pledge to increase the sustainability of the housing sector (P4). These collaborations can aid in providing clarity among private actors on the ambitions within the different municipalities as well as increase knowledge sharing (R3, R8, P4). This is especially useful for municipalities to increase their level of knowledge (R11). This knowledge sharing can be extremely helpful to aid municipalities to legally bind and futureproof sustainable building techniques like biobased into their policies (R9, R11). However, important to not is the fact that these covenants are not legally binding (R9, P4). A respondent emphasised the need for juridical binding agreements since those provide more stability for the long term (R9). The province is working on creating easily accessible knowledge for municipalities to support local officials in creating feasible policies (P3). Furthermore, it was mentioned that the province can create opportunities for the niche by working with Building Balance (R4). Besides working with Building Balance, the province can also investigate the

possibilities for collaborations with housing corporations into making agreements on their future developments surrounding their housing stock (R4, R7, R10, R11). This can aid in the creation for a steady demand for biobased building materials. A respondent also emphasised the importance of company visits by the province to share knowledge and to gain valuable relevant insights within the biobased sector (R5).

4.3.6 Municipalities

Respondents mention the significant impact a bidding process by the municipalities enact on the construction sector (R9, R11). An example that was given is the usage of 'Het Nieuwe Normaal 1.0' (HNN) by municipalities to determine the circularity of a new development. This policy is more is more ambitious then the current MPG legislation and can aid a municipality in choosing the most circular development (R1). The HNN policy uses the MPG as a baseline and introduces several adjustments to reduce the current bias towards traditional building materials. More importantly, this policy does not produce a total score of a development but rather gives multiple scores of individual circularity indicators (P1). This provides a more integral insight into the aspects of a development and allows for an individual approach for each project (P1). This allows for the a more tailor-made approach since different projects can prioritise different indicators (P1). Building companies prefer national legislation over regional legislation to prevent unnecessary complicating the regulatory environment (R1, R5). A respondent mentioned that this can be prevented by assessing the current bidding process policies in their neighbouring municipalities (R1). The HNN is more widely adopted than other policies with over 80 municipalities having implemented the HNN policy (R10)
(R10. The integration of the HNN policy can have a positive effect on the local biobased building material market. The example that was given is the municipality of Leeuwarden in the province of Friesland. In this municipality the HNN policy was integrated into their bidding process which had a positive effect on the local biobased building material market (R11). However, the impact of these bidding policies is not endless and should be supported with sound collaborations with private actors (R11). Furthermore, The current iteration of HNN is found to be cumbersome and time intensive (R9). Similar to the current national legislation, the assumptions in HNN are prone to change which negatively impacts the support of private actors (R9). Besides a progressive bidding policy, the municipalities can also work with flex dwellings to temporarily lift the pressure on the local housing market (R10, P3).

4.3.7 Knowledge

A respondent mentioned a concrete example of resolving the knowledge gap present within the user group (R11). The example given surrounds the insulating of social housing within the province of Friesland. The housing corporations is collaborating with their maintenance and construction partners to gain an insight in the knowledge gap (R11). The maintenance and construction partners are updated on the ambitions of the housing corporation and asked to list their requirements to gain the necessary know-how to be able to complete the insulation task (R11). This information is then provided using workshops and expert advice presentation. This method is directly injecting the user groups with the required information and fast tracks them into being able to work with biobased building materials (R11). Furthermore, the role of architects is mentioned (R3, R8). The low usage of biobased building materials resulted in a current lack of knowledge among architects (R6). The level of knowledge among architects is an important factor when adopting biobased building materials since this allows for the integration these materials in the design process of new housing developments (R6). Architects are currently working on sharing information between the sector as well as developing of new design software (R3). The example given is Madaster, this initiative was

first set up by architects and is aimed to make the re-use of construction materials easier (R3) It was emphasised that these initiatives also have a flip side since it can be a means to justify using traditional materials by endlessly re-using them (R3). This re-usability is questioned due to changing regulation and the energy input required to re-use these building materials (R3). Furthermore, architects are designing a new construction method which directly link the used materials to the actual costs of the materials including the shadow costs which are currently not taken into account (R3). This makes it easier for architects to justify using more expensive materials by comparing the actual social costs of materials (R3). However, it should be noted that the development of this new design method is dependent on European norms which have not yet been developed (R3). Lastly, It was noted that the interest and knowledge surrounding biobased building materials is growing (R2, R3). This is also fortified by the creation of the wood lobby group as a counter to the concrete- and steel lobby groups (R3, R5). It is noted that due to the wood lobby is not as invested and mature as the concrete- and steel lobby since it was only recently set up which hinders their influence (R3).

5. Discussion

In this chapter the sub-questions will be answered by using the interview data in combination with the literature review.

5.1 The current position of biobased building materials

In this section the first sub-question: '*How are biobased building materials positioned in the current Dutch house building system'* is answered. The current position of the niche in the Dutch house building system is based on developments within the three analytical levels of the MLP framework. First, an analysis of the recent landscape developments revealed that the landscape is actively trying to stimulate the adoption of biobased building materials. The European Union this us represented by the Green deal and subsequent creation of the EN15804 (A2). The Dutch national government is only recently stimulating building with biobased building materials by implementing their first biobased policy document in 2023, called the NABB. This solidified the important role biobased building materials will have in making the Dutch house building system more sustainable in the future. This policy document is supplemented with the introduction of various subsidy programme's (MIA and the VAMIL) as well a collaboration with financial actors to provide green loans with lower interest rates for green developments. Similar landscape developments where also found at the forefront of widespread adoption by Geels (2002). Besides the landscape, there have also been recent developments within the regime.

While the current regime is reluctant to transition towards biobased building practices. Larger firms are experimenting with their own biobased concepts which are currently utilised on a smaller scale. The biobased building material niche has also been further developed resulting in more competitive alternatives to traditional building materials. For example, biobased insulation made from domestically grown hemp and prefabricated facades made from Dutch wood. Furthermore, the niche is currently working on the creation of new standardisation methods, in this case the creation of new NEN and ISSO norms. However, analysing the adoption of biobased building materials also reveal that the niche has not been widely adopted by the current house building system. This is exemplified by the low shares biobased building materials currently have within the total used building materials.

The above mentioned developments across the three analytical levels places the current position of the biobased building material niche in the second phase of a technological transition according to Geels (2019). However, this research also revealed that a promising development method for biobased building materials is integrating them into the current house building system by the means of the hybrid construction form and flex dwellings. This hybridisation is generally found at the forefront of widespread adoption within the regime according to Geels (2002). Therefore, while currently residing in the second phase. It can be further concluded that some more developed biobased building materials are residing at the end of the second phase.

5.2 Hindering factors of biobased building materials

The second sub-question to be answered is: '*Which factors hinder the adoption of biobased materials in the Dutch house building system?'* The answer to this sub-question resides in multiple levels namely the landscape, regime and the niche. In the next section the hindering factors will be outlined per level.

Landscape

The existing landscape is creating multiple hindering factors which negatively influences the adoption process of biobased building materials in the Dutch house building system. First, the Dutch national government integrates the European policy EN15804 differently than other member states. While this approach by the Dutch national government aimed to increase the circularity in the Dutch building sector. The different integration of various sustainability factors outlined in the EN15804 makes it more difficult for foreign biobased initiatives to enter the Dutch biobased building material market. This is due to the fact that it requires foreign biobased initiatives to comply with stricter Dutch requirements. This resulted in less foreign suppliers which resulted less total supply of biobased building materials overall in the Dutch market. This increases the susceptibility of the Dutch market to fluctuations in supply and demand which negatively influences the adoption process of biobased building materials by the Dutch house building system. While the concrete effects of this isolation of the Dutch national building material market have not been researched previously. The isolation of the market and subsequent susceptibility to fluctuations in supply and demand increases the perceived risks associated with using biobased building materials. According to Van Oorschot et al. (2020) this negatively influences the adoption process of an innovation, in this case biobased building materials, within a house building system.

Second, there is a distinct lack of unambiguous long-term national policies. While the national government aimed to provide this unambiguous long-term policy in the NABB. In this policy document itself it states the fact that the outlined interventions are not definitive and can be altered due to new insights or even scrapped altogether. This creates uncertainty among building companies since it increases the chance that the path chosen by biobased building material companies is sidelined by changing governmental ambitions. This uncertainty increases the risk for building companies to invest and change their production processes now rather than in the future. This is due to the fact that these risks will diminish over time when the exact policies become clear. The influence of the lack of unambiguous long-term policy is confirmed in previous literature (Smith et al., 2005). In addition, this risk adverse behaviour by companies has been 'rewarded' in the past with the often changing stance of the Dutch national government regarding the 'salderingsregeling' for solar panels and the lifting of the obligation of a hybrid heat pumps. This track record of changing governmental stances on climate ambitions and policies diminished the credibility of the longevity of new policies. This is due to the fact that while the governments current aim may be on stimulating biobased building materials. If this aim changes and perhaps favours a different building practice this will most likely negate all investments done by building companies in developing the biobased building materials niche. Subsequently, this results in the fact that building companies are hesitant to invest and develop biobased building materials due to this lack of credible and unambiguous governmental policies. This risk adverse behaviour due to uncertain government regulations is also confirmed in previous literature (Dams et al., 2023; Gottlieb et al., 2023).

Thirdly, there is an institutional and political lock-in mechanism at play within the current MPG regulations. This is due to the current iteration of the MPG encompassing several in-built biases favouring traditional building materials. Previous literature also confirm that existing regulations and standards generally favour the status quo (Atkinson et al., 2014; Dams et al., 2023; Geels, 2019; Gottlieb et al., 2023; Hurmekoski et al., 2015). The in-built biases are categorised into two distinct categories namely the data side (NMD) and the assumptions used in the calculation method of the MPG. First, the current available data for biobased building materials in the NMD database is insufficient. This results in the fact that most data regarding biobased building materials is classified in the third data category. This category is subject to a 30% uncertainty tax which has a substantial negative effect on the sustainability ratings of biobased building materials. The available data regarding traditional building materials is significantly more substantial and results in their classification into the more favourable first and second data categories. This disparity of available knowledge within the NMD database hinders the adoption of biobased building materials since it negatively influences the competitiveness of these new materials. The influence of incomplete databases on the adoption process is also confirmed in previous literature (Dams et al., 2023).

Within the calculation assumptions, there are two main factors which are disproportionately negatively impacting biobased building materials. First, the current end-use scenarios for biobased building materials are not realistic. For example, the current end-use scenario of wood is incineration. While it is true that certain wooden building materials will be incinerated after their life span. What is currently not taken into account is the fact that, before the incineration takes place the wooden building material can be cascaded multiple times and thus be reused extending its effective life-span. This disproportionately effect biobased building materials since they are better suited to be re-used and also recycled in high-end purposes. In the current calculation methods, biobased building materials reap little to no benefit from these favourable characteristics. Secondly, the effect of carbon storage is currently not included in the calculation of the MPG. This negatively affects biobased building materials since these materials generally store significantly more CO_2 then traditional building materials. The exclusion of carbon storage therefore favours traditional building materials in the current MPG calculations. Both factors artificially improve the competitiveness of traditional building materials compared to their biobased counterparts. According to the innovation adoption framework by Van Oorschot et al. (2020), this negatively influences the adoption process of biobased building materials in the Dutch house building system.

Furthermore, the current housing shortage and subsequent high prices raise concerns within the national government and the Dutch house building system. There are concerns that a shift towards a new production process will lead to higher prices which will increase the already high housing prices even further. As a result, the national government is hesitant to implement more ambitious regulations like tightening the MPG. The national government is dependent on professional associations and interest groups for information regarding the current developments of the market. This consultation is necessary to ensure that realistic policies are implemented and to prevent the sidelining of a significant share of the production capacity. However, this participatory aspect of policy does result in the fact that the current interests of the regime can alter certain aspects of new policies. Multiple interviews mention the influence the of powerful lobby groups had within the consultation process of the MPG. This influence was also found in earlier research on the influence of professional associations and interest groups on new regulations surrounding the Dutch concrete industry by Vermeulen et al.

(2007). The absence of a well established wood and or biobased building material lobby limit the abilities of the niche to express their interests in the existing policy networks.

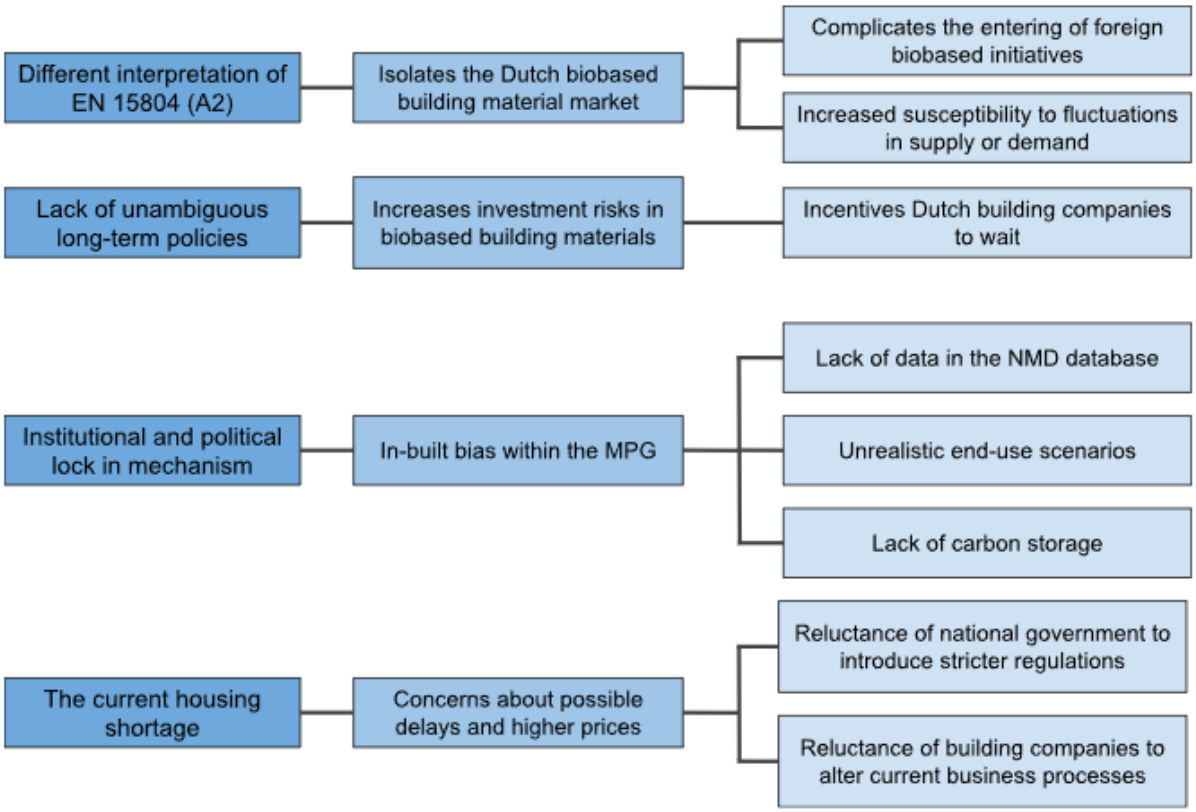

Figure 15: Overview of hindering landscape factors

Regime

Within the regime there are two distinct lock-in mechanisms at play which hinder the adoption of biobased building materials within the Dutch house building system. First, there is a strong techno-economic lock-in mechanism negatively influencing the adoption process of biobased building materials. The business processes within the Dutch house building system are designed around the use of traditional building materials. As a result, large research and development investments have been made to innovate the manufacturing process of traditional building materials as well as the installation of said materials. The introduction of a new building process using different building materials jeopardizes these investments which results in significant sunk costs. Also, the current house building system in the Netherlands still uses mostly traditional building materials. Therefore, the current house building system is still reaping benefits from the manufacturing and use of traditional building materials. This makes the current house building system reluctant to transition towards a different building process like biobased. This reluctance is also found in earlier research surrounding techno-economic lock-in mechanisms by Atkinson et al. (2014) and Geels (2019).

Previous research by Dams et al. (2023) and Gottlieb et al. (2023) found that traditional building materials currently have significant benefits compared to their biobased counterparts. This is also the case for the traditional building materials currently being used by the Dutch house building system. Traditional building materials in the Netherlands are generally cheaper and higher performing then their biobased counterparts. This is due to their long-term application in the Dutch house building system granting them decades of incremental

improvements in addition to providing significant economies of scale which reduces their unit price. This negatively impacts the adoption process of biobased building materials since traditional building materials provide a cheaper and higher performing alternative. This cost-oriented focus is confirmed in previous research (Van Oorschot et al., 2020).

The current minimum circularity norm in the MPG can still be relatively easy be achieved by using mainly traditional building materials. As a result, there is no direct necessity for the Dutch house building system to adopt biobased building materials since their efficient business process still complies with the existing regulations. Furthermore, the interviews highlighted the current lack of an existing reward structure for the house building system when achieving above MPG standards. Achieving above MPG standards accommodates additional costs due to the implementation of more expensive biobased building materials. These additional costs negatively influence the business case of a project which must be compensated elsewhere in the business case. While this extra cost can be recouped by increasing the prices of new homes. The current housing shortage and subsequent high prices limit the ability of this measure. Therefore, achieving above-standard ratings results in a poorer business case for building companies. This lack of incentive can result in the fact that business cases for new housing developments becomes economically unfeasible. An example is the ‘Woontoren Duet’ in the city of Nijmegen. The municipalities above MPG standard circularity ambitions put pressure on the economic viability of the business case. After the bidding was awarded, it became clear that the project was economically unfeasible in its current iteration which led to long delays. This increased economic impact of using biobased building materials on the business case is a significant factor and is also confirmed in previous research by Dams et al (2023) and Gottlieb et al. (2023).

Also, the development and subsequent adoption of biobased building materials by the Dutch house building system is accompanied with significant financial risks. The development effort of a chosen biobased building material can turn out to be a technological dead end. This results in significant sunk costs which can not be recuperated. Furthermore, the adoption of biobased building materials by the existing house building system is complicated and expensive. This is due to the need to extensively test the properties and characteristics of these new biobased materials when implementing them into the existing business process. This test may reveal the need for the building company to retool their production facility due to different material properties and characteristics. Testing may further reveal a difference in installation time of the new biobased counterpart. This may result in the need to alter the entire production process which significantly increases the costs of adopting biobased building materials. Also, the current lack of a reliable and sufficient biobased production chain requires companies to set up their own chain which further increases the cost associated to the development and adoption of biobased building materials. These risks result in in the fact that building companies developing and adopting these materials will be asked to take on significant financial risk with a limited profitability prospect. This is due to the current low demand of biobased building materials. This makes financial actors and building companies hesitant to invest in biobased building material ventures, this is confirmed in the literature (Atkinson et al., 2014; Dams et al., 2023).

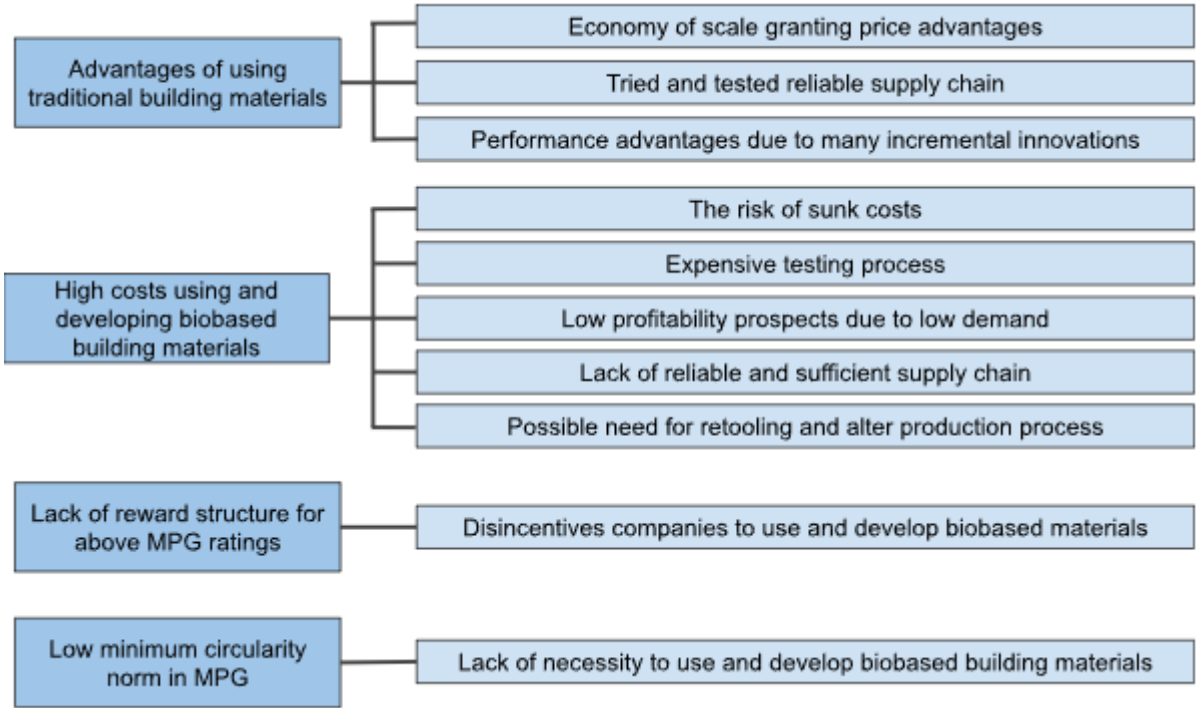

Figure 17: Overview of the techno economic lock-in mechanism present in the regime

The second lock-mechanism regards the social and cognitive lock-in mechanism at play in the current building regime. Traditionally, the Dutch house building system worked exclusively with traditional building materials. Educational institutions also traditionally focussed on installing, manufacturing and designing with traditional building materials. This created significant databases of technical knowledge regarding the installation (ISSO norms) and specialised design techniques. These databases, technical knowledge and design techniques are not yet developed for biobased building materials. The lack of technical data and experience within the Dutch house building system hinders the adoption of biobased building materials. This is also confirmed in previous research (Gottlieb et al., 2023; Williams & Dair, 2007).

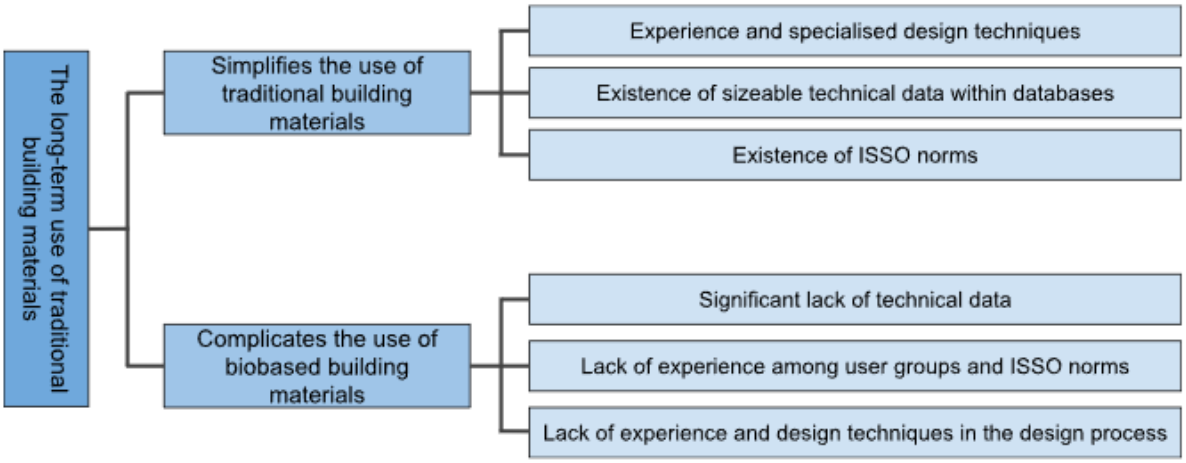

Figure 16: Overview of the cognitive lock-in mechanism present in the regime

Niche

There are three main hindering factors present within the biobased building material niche. First, there is the fact that the supporting industries of biobased building materials in the Netherlands are underdeveloped. Especially compared to the supporting industries of traditional building materials. The development of both supporting industries of biobased building materials is hindered by what is referred to in several interviews as the chicken/egg phenomenon. This phenomenon revolves around the high dependency of sale guarantees to reduce the risks for the supporting industries. The agricultural industry (farmers) require sale guarantees for their biobased materials. Without sale guarantees, the financial risk of transforming farmland to cultivate biobased materials is too significant. This is because without them, farmers are required to invest significant funds while a return on these investments is not guaranteed. However, the processing industry is hesitant to supply farmers with sale guarantees since it would mean that they would set up a factory without an existing and tested supply chain. This same dynamic is also experienced between the processing industry and the producer network. The producer network is hesitant to work with biobased building materials since the required processing industry in the Netherlands is still insufficient. As a result, the producer network would be required to set up a business process based on a not yet existing and tested supply chain. However, the processing industry on the other hand requires these sale guarantees before setting up their industries. This is because without a sale guarantee, the processing industry is setting up factories while not knowing if the manufactured products will be sold. This dependency on sale guarantees results in a development stalemate between the agricultural, processing and building industries. This lack of development by the supporting industries prevents the upscaling of available supply of biobased building materials. This hinders the adoption process of biobased building materials in the Dutch house building system due to the lack of available biobased building material supply. This is confirmed in previous research (Dams et al., 2023; Gottlieb et al., 2023).

Secondly, according to Dams et al. (2023) the biobased building material market is a difficult market to enter. This is attributed due to the high initial investment required to set up a biobased building material company. This cost is further increased by the Dutch certification process of new biobased building materials which is cumbersome and expensive. The requirement to provide additional data to the NMD database further increases the costs within this process. As a result, most biobased building materials lack certifications and are placed in the category 3 in the NMD. This negatively affects the competitiveness of biobased building materials compared to their traditional counterparts. Furthermore, biobased building material companies also experience difficulties obtaining sufficient capital to develop their business processes. Financial actors are hesitant to grant loans to starting biobased companies and only provide loans when the first start-up and scale-up has been achieved. This makes it incredibly difficult for new Dutch biobased building material companies to develop their business process due to these limited financing options. In addition to the limited financing options, lies the fierce competition traditional building materials provide. These materials enjoy significant advantages related towards price, availability, knowledge, and regulations and standards. These factors combined make it extremely difficult for starting biobased building material companies to gain a foothold in the market. This is confirmed in previous research (Van Oorschot et al., 2020)

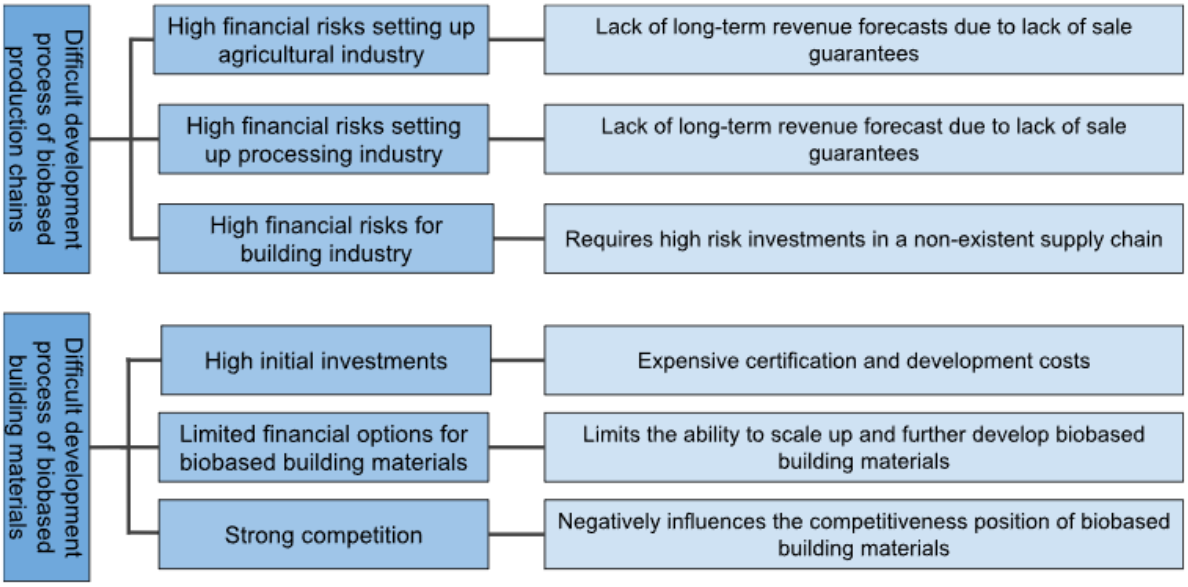

Figure 18: Overview of hindering factors in the niche

5.3 Stimulating factors of biobased building materials

The last sub-question to be answered is: '*Which factors can stimulate the adoption process of biobased building materials in the Dutch house building system?'* There are multiple factors within the landscape, regime and niche level which can stimulate the adoption process of biobased building materials in the Dutch house building system. Similar to chapter 5.2, the stimulating factors will be outlined per level.

Landscape

The national government can stimulate the adoption process of biobased building materials in the Dutch house building system. The national government can aid in this process by creation a more regulatory environment. This entails interpreting the European legislation EN 15804 (A2) similar to other member states. This simplifies the process for foreign biobased building material initiatives which incentivises them to enter the Dutch market. This has a positive effect on the availability of biobased building materials due to an increase in the total amount of biobased building materials as well as the number of suppliers. This also decreases the current susceptibility of the Dutch biobased building material market. Sudden changes in supply or demand can namely be cushioned by other biobased building material markets in other member states. The existence of a robust market of biobased building materials will decrease the perceived risk experienced by the Dutch house building system. While the effect of the different interpretations of EN15804 (A2) has not been researched previously. According to Van Oorschot et al. (2020), decreasing the perceived risk will positively influence the adoption process of innovations in the Dutch house building system.

Secondly, the national government can stimulate the adoption process of biobased building materials by creating long-term unambiguous policies. This is crucial since it provides the Dutch house building system with valuable information to schedule their investments and prepare their business processes. Furthermore, the introduction of long-term unambiguous negates the current 'reward' for passively waiting by building companies. This is due to the fact that passively waiting will negatively impact a companies future ability to stay competitive in the Dutch house building system. Important in this process is the trust of private actors that these governmental ambitions will not change over time. This can be achieved by, similar to France and Germany, setting long-term ambition which are not dictated by a current elected administration. This is due to the fact that these long-term ambitions will be less subject to constant alteration since they are better entrenched in Dutch laws. This increases the credibility of these policies which according to Smith et al. (2005) positively influences the support and subsequent adoption by the Dutch house building system.

Thirdly, the national government can stimulate the adoption of biobased building materials by reducing the current institutional and technical lock-in mechanism present within the current MPG regulation. According to Van Oorschot (2020), government regulations are critical to the adoption of new innovations in the Dutch house building system. This research found three main factors in the current MPG which, when altered, can level the playing field for biobased building materials. First, there is a need to critically examine the accuracy of the current assumptions of biobased building materials in the MPG since the current end-use assumptions are favouring traditional building materials. This is due to the fact that biobased building materials are more suitable to be re-used into high-end purposes. While the characteristics of traditional building materials make them generally more suitable for low-end purposes like to serve as the foundation for new highways. Adjusting these end-use assumptions will increase

the accuracy of the MPG and increase the competitiveness of biobased building materials. Secondly, the MPG can improve its accuracy by integrating carbon storage into the current calculation. The absence of carbon storage disproportionately affects biobased building materials since they generally store significant amount of carbon. The integration of carbon storage increases the accuracy of the MPG by more realistically depicting the actual properties and characteristics of biobased building materials. This will improve their circularity ratings which will make them more competitive to their traditional counterparts. While the MPG as a case has not been researched previously. The above-mentioned adjustment improves the accuracy of the MPG removing the current in-built bias which results in a level playing field for biobased building materials which stimulates their adoption. This is confirmed in previous research (Gottlieb et al., 2023).

Besides the calculation of the MPG, the current NMD database has significant knowledge gaps regarding the properties and certifications of biobased building materials. According to Gottlieb et al. (2023), this lack of knowledge significantly hinders the adoption process of biobased building materials. This places most biobased building materials in the third category which artificially decreases their circularity rating due to the 30% surcharge. This artificially negatively impacts the circularity rating of biobased building materials. The national government can increase role of Building Balance to offer more assistance to biobased building material companies in creating the necessary data. This is especially relevant for smaller biobased building companies since they generally lack the in-house expertise and resources to develop this data on their own. Lastly, the current tightening of the MPG regulations is not happening fast enough. The mandatory level of circularity dictated in the MPG can still be relatively easily achieved while still mainly using traditional building materials. This reveals an urgent need to tighten the current MPG regulation to incentive the Dutch house building system to adopt biobased building materials into their developments. The positive influence of governmental legislation is confirmed in previous research (Dams et al., 2023; Dewick & Miozzo, 2002; Gottlieb et al., 2023; Van Oorschot et al., 2020).

The provincial and municipal governments can exert influence to expedite the adoption process of biobased building materials in their respective landscapes. Provinces and especially municipalities can introduce policies which stimulates the adoption of biobased building materials. Provincial and municipal policies are more versatile and can be better adapted to their respective landscapes. Moreover, these local policies can be implemented significantly faster than national policies. This provides local governments the ability to supplement the current gaps of the national MPG policy. Multiple interviews revealed the positive influence municipalities can exert by altering their bidding processes to stimulate the use of more sustainable building materials like biobased. The effects of local policies have not been researched previously and can thus not be confirmed directly. However, the introduction of these municipal policies incentivises building companies to use more sustainable building materials in order to comply with municipal regulations. This in turn creates stimulating regulations which according to Van Oorschot et al. (2020) increases the likelihood of the house building system adopting biobased building materials.

Municipalities should work diligently when implementing more ambitious policies. To increase the effectiveness of more ambitious bidding process policies, municipalities should prevent creating a needlessly complicated regulatory environment. This can be achieved by aligning their bidding process policies with surrounding municipalities. Multiple interviews deemed this critical to the effectiveness of these policies since different policies in each municipality can

overwhelm building companies. This leads to an increase in costs of new housing development as well as causing significant delays. This is due to the fact that building companies will be required to alter their business processes for each bidding process in each municipality. Furthermore, multiple interviews revealed a current lack of in-house knowledge present among municipal officials regarding biobased building materials. This decreases their ability to implement more ambitious policies.

The provincial government can assist municipalities in this process by the creation of a covenant. Within this covenant, municipalities and the provincial government can collaborate with private actors to create feasible policies. This can aid in the creation of a province wide ambitious bidding process. A promising method to achieve this is by implementing the HNN into a covenant. The HNN is promising since it improves the workings of the current MPG regulation by removing the current in-built bias. Furthermore, the HNN provides multiple scores across several circularity indicators instead of a singular circularity rating like in the MPG. This provides a better insight into the circularity of a building and further allows a tailor-made approach across different projects. This is crucial since this prevents sidelining significant parts of the local house building system due to the implementation of the HHN. This is due to the fact that the scores in the HNN are not hierarchical. This allows municipalities to adapt the policy to their local house building system.

While a covenant is not legally binding, it does solidify the provincial- and municipal governments preference and dedication to biobased building methods. Besides coordinating collaborations between private actors and the municipalities. The provincial government can also dictate the agricultural policy in their respective region. This agricultural policy can be used to stimulate the growth of biobased fibre crops which increases the amount of agricultural land in a province dedicated to the creation of biobased building materials. This is crucial to increase the production of biobased materials which can be made into biobased building materials. The utilisation of using local policies to stimulate the adoption process of biobased building materials is not identified in previous research regarding the adoption process of these materials. However, a stimulating agricultural policy incentivises farmers to cultivate biobased materials which can lead to an increase in supply. According to Dams et al. (2023), this is crucial to allow biobased building materials to be more widely used in the house building system.

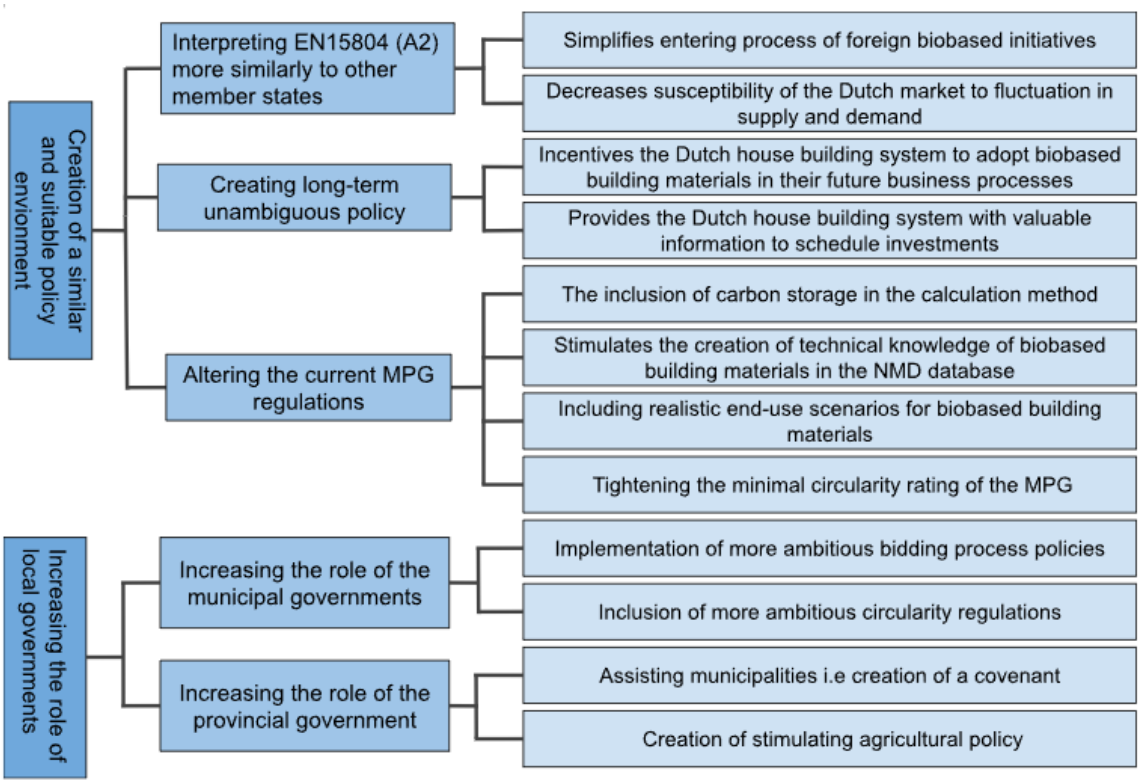

Figure 19: Overview of stimulating factors on the landscape level

Regime

This research revealed two promising methods to decrease the influence of both the techno economic and social cognitive lock-in mechanism. The first method is introducing a hybrid construction form into the business process of a building company. This method entails the gradual replacement of traditional building materials with a biobased counterpart. This method significantly reduces the financial risks since a building company can gradually adopt biobased building materials into their business process. According to Van Oorschot et al. (2020), this reduced financial risk positively influences the adoption process of an innovation, in this case biobased building materials, in the Dutch house building system. This is due to the fact that the hybrid construction form reduces the amount of financial capital required by building companies since it negates the need to alter their entire business process all at once. Furthermore, implementing a hybrid construction form also allows building companies to gradually adapt to changing regulations. When stricter regulations are being implemented, building companies can swap out a building material with a more sustainable biobased counterpart. A hybrid construction form also allows building companies to swap out a biobased building material with a traditional counterpart if for instance, the biobased building material is unavailable. This is important since the current biobased supply chain is limited in size. This reduces the risks of a delay in construction process which reduces the perceived risks of adopting biobased building materials using a hybrid construction form. According to Van Oorshot et al. (2020), this has a positive effect on the adoption process of biobased building materials in the Dutch house building system. Building companies can best make use of the hybrid construction form when they first replace traditional building materials with the most advantageous, compatible and economically feasible biobased counterparts. This is confirmed in previous research (Van Oorschot et al., 2020).

The hybrid construction form also presents an opportunity to reduce the social and cognitive lock-in mechanism present in the current system. The gradual introduction of biobased building materials allows architects, the user groups, the producer network and the supplier network to familiarize themselves with biobased building materials. Architects gain first hand experience when altering parts of their designs to integrate these materials. This creates knowhow regarding the design techniques that work well with biobased building materials as well as unsuitable design principles and techniques. This allows architect to develop specialised design techniques to be used when working with biobased building materials which significantly positively influence the adoption process of these materials. This is confirmed in pervious research (Gottlieb et al., 2023; Williams & Dair, 2007). While the educational institutions are already facilitating the diffusion of specialised design techniques among students. The hybrid construction method grants the unique opportunity to diffuse this information among experienced architects. This direct injection of knowledge among already graduated and experienced architects reduces the time required for this new information to make its way up the 'food chain' of established architectural firms. Furthermore, this method also allows members of the user groups such as contractors to gain firsthand experience with working with biobased building materials. This also allows for the creation of more technical knowledge when installing these materials. This technical knowledge can in turn be used to expedite the creation of new ISSO norms which are vital to the various user groups when working with these new materials. The first-hand experience in addition to the creation of ISSO details grants the ability to quickly diffuse the information among all members within the user group. This has a significant positive effect on the adoption process of biobased building materials in the current Dutch house building system. This is also confirmed in previous research (Dams et al., 2023; Gottlieb et al., 2023; Williams & Dair, 2007).

The hybrid form allows building companies to first integrate the most advantageous and compatible biobased building materials. This grants the supplier network valuable time to further develop suitable and profitable manufacturing techniques for less developed biobased materials. According to Gottlieb et al. (2023), this is a crucial factor in the adoption process of biobased building materials. Besides the hybrid form there is a more extensive method focussed on the development of flex dwellings. While the market for flex dwellings is, at the time of writing, still fairly lacklustre. The demand of flex dwellings is gaining momentum since their temporary nature grants them a simpler planning permission process. This make flex dwellings extremely well suited to temporarily lift the current pressure on the housing market while new permanent housing is being built. Also, the municipality can grant flex dwellings permanent planning permission. The benefit of flex dwellings is that this slow and long planning permission process can take place while the flex dwelling is already built and utilised.

Biobased building materials are well suited to be used in the building process of flex dwellings. This is due to the fact that biobased building materials have significantly better detachability characteristics than traditional counterparts. This is important since the temporary nature of flex dwellings may result in the relocation of the construction which will be significantly simplified and cost-effective when made from biobased materials. The usage of biobased building materials will similarly to the hybrid construction form further allow architects, user groups and the supplier network to further familiarise themselves with these materials. The gradual implementation of both hybrid construction and flex dwellings can also aid the development of biobased building materials since it increases the demand. This improves the economic viability of developing these materials since the costs can be spread out over more units.

However, while the hybrid construction form and flex dwellings reduce the implementation risks of biobased building materials in the current house building system. The current prices of biobased building materials are higher than their traditional counterparts. This is especially relevant for building companies since they operate in an extremely price competitive field. Housing corporations and the government can function as launching customer which allows for the further development of the hybrid construction form and flex dwellings. Furthermore, the increased demand due to implementation of these methods among launching customers is beneficial for the further development of the biobased building material niche as a whole. This is confirmed in previous research (Gottlieb et al., 2023). However, while housing corporations express a willingness to increase their usage of biobased building materials. Their resources are not endless since they are still required to develop sufficient social housing in line with national set agreements. Therefore, the success of both the hybrid construction form and flex dwellings remain dependent on the further development of the biobased building material niche.

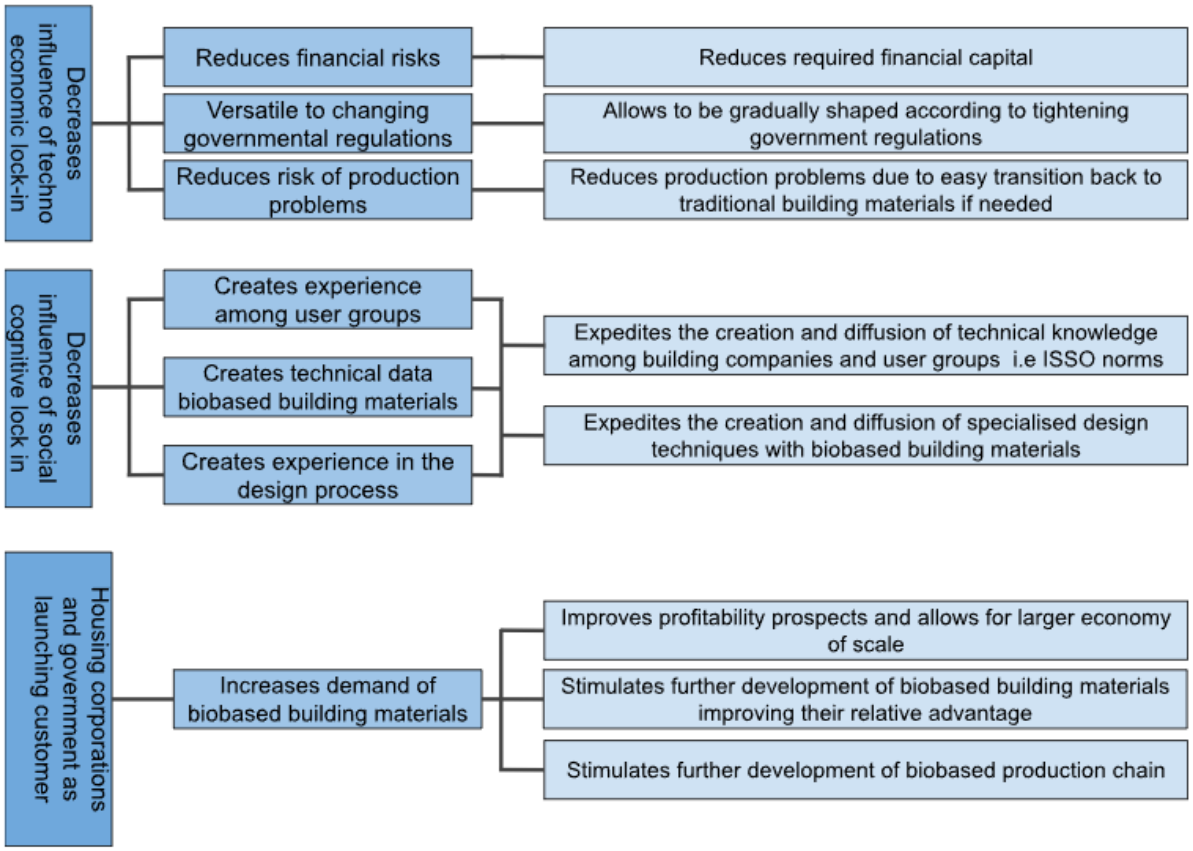

Figure 20: Overview of stimulating factors using both hybrid construction form and flex dwellings

Niche

The further development of the biobased building material niche in the Netherlands is crucial to expediate the adoption process of these materials. First, there is the need to further develop the biobased production chain to increase the availability of biobased building materials to a level where it can be used on a wider scale. This is a crucial factor since a discrepancy between the supply and demand of biobased building materials will impose negative effects on the adoption process, this is also confirmed in previous research (Dams et al., 2023; Gottlieb et al., 2023). The development of supporting industries of biobased building materials

is crucial to increase the availability of these materials. The current development of these industries is in a stalemate due to two similar chicken/egg dynamics. While the national government is already working on the creation of local biobased production chains. This development is happening to slowly to achieve the ambitions outlined in the NABB. Private intermediary companies can supplement the efforts from the national government and can expediate the creation of biobased production chains. The positive influence of intermediary companies to alleviate both chicken/egg dynamics emerged in several interviews. Intermediary companies, similar to the efforts from building balance, collaborate with companies of all three links in the biobased production chain. This collaboration allows the three industries to negate the influences of the current chicken/egg dynamics and creates the possibility to create a viable business case when setting up a biobased production chain.

While no previous research exists regarding the effectiveness of these private intermediary companies in the creation of more substantial biobased production chains. Intermediary companies can reduce the workings of the current chicken/egg dynamic which leads the further development of biobased production chains. This simplifies the adoption process of biobased building materials since building companies will no longer be required to develop their own biobased production chains when using these materials. These two factors are found in previous research to positively influence the adoption process of new innovations in the Dutch house building system (Van Oorschot et al., 2020).

An important factor when developing the biobased building material niche is the unique characteristic of biobased building materials. The growth of new biobased materials takes time which limits the ability to accommodate large fluctuations in demand. To prevent future disparities between supply and demand the building industry information regarding the future demand of biobased materials is crucial. An insight into the future demand requirements for the Dutch house building system allows the biobased building material niche to gradually scale-up and increase their growth and manufacturing capabilities. The development of these companies due to the larger demand also enables them to allocate more resources to the research and development of biobased building materials. Furthermore, companies in the niche will be able to take advantage of early benefits that comes with economies of scale. The development of the niche will positively influence the adoption process of biobased building materials due to an increase in economic feasibility, availability and relative advantage compared to traditional building materials. This is confirmed in the literature (Gottlieb et al., 2023; Van Oorschot et al., 2020).

A small number of housing corporations are already working on mapping their future biobased building materials needs. However, this current effort is small in scale. It is crucial that this mapping process of future demand is expanded to also include building companies in the Dutch house building system. The provincial government can expedite this process including this information into a covenant. While no previous research exists that can confirm the effectiveness of a provincial covenant. The positive influence of the early mapping by several housing corporations emerged in several interviews. Another important factor in stimulating the adoption process is the existence of product certifications of new biobased building materials. According to Dams et al. (2023), these certifications increase the trust in these new materials and increases the likelihood of private actors using them in new developments. This was also found in the case of the Dutch house building system. Building companies and housing corporations both expressed the need for product certification to reduce the risks of liability down the road. Wile the national government assist biobased building material

companies in obtaining these certifications. The lack of certification, and to a larger extent, the lack of data in the NMD database reveal that this effort should be increased. According to Dams et a. (2023), this positively influences the abilities of smaller companies to obtain the necessary certifications.

Lastly, there is the need to develop the financial opportunities for the biobased building materials niche. Currently the biobased building niche is a difficult market to enter due to the high up-front investments and relatively low demand. This increased risk makes financial actors hesitant to provide capital to companies operating in the biobased building material niche. This disproportionally hinders smaller companies to enter the biobased building materials market. This is due to the fact that larger biobased building companies, often backed by a larger parent company, are able to more easily obtain the required capital to develop their product and manufacturing capabilities. According to Gottlieb et al. (2023), to level the playing field, the government can collaborate with financial actors to provide special low-interest loans for green innovations. The Dutch national government has already implemented this to some extent which had a significant positive effect on creating opportunities for smaller companies entering the biobased building material niche. However, this research revealed that the current programme is in need for expansion to provide the niche with sufficient financial opportunities to further develop their products and manufacturing capabilities.

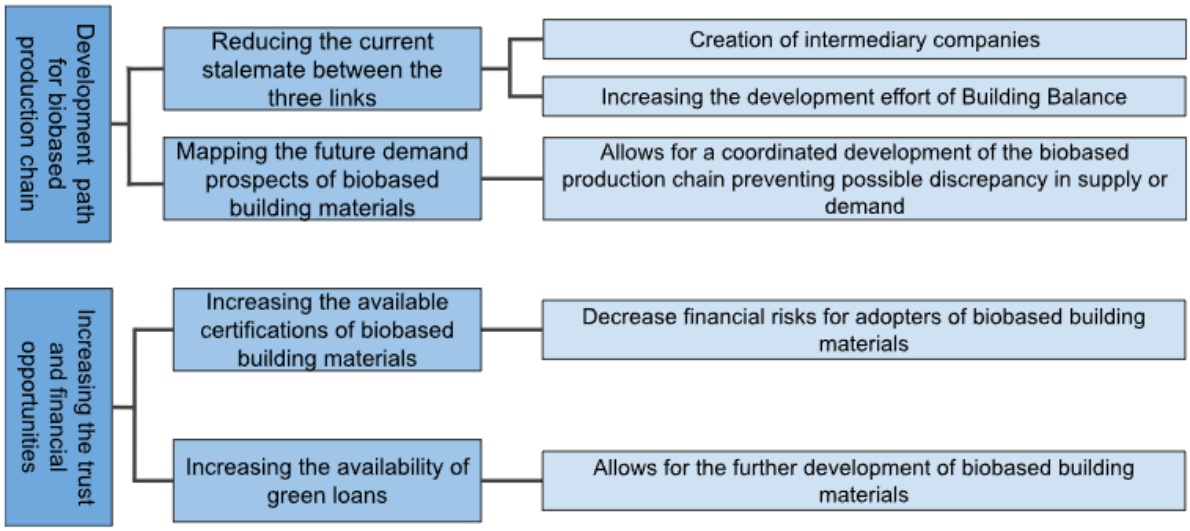

Figure 21: Overview of stimulating factors on the niche level

5.4 Recommendations for future research

In this section the recommendations for future research will be outlined. The current available body of knowledge of the adoption process of biobased building is limited. Further research is thus needed to confirm the findings in this study regarding the hindering and stimulating factors of the adoption process in the Dutch house building system. Furthermore, the current adoption process of biobased building materials in the Dutch house building system is an ongoing process. Future developments in this transition can result in new hindering and/or stimulating factors which influences the adoption process. Therefore, continued research on the development of this transition is required to confirm the existing knowledge and to supplement it.

This research outlined multiple hindering and stimulating factors to expedite the adoption process of biobased building materials in the Dutch house building system. The most significant findings in need for further research are outlined. First, this research revealed the need for a refinement of multiple elements in the current MPG regulations. This research found that the altering of these elements will improve the accuracy of the MPG regulations. Future research into the exact details as to how these elements should be altered is necessary. This provides policy makers with scientifically founded recommendations as to how to best increase the accuracy of the MPG regulations. Also, this research outlined two methods to decrease the implementation risks of biobased building materials in the current house building system. However, little to no information depicting the most effective and feasible implementation strategies for building companies in the Netherlands is available. Therefore, this requires further research. This future research should delve deeper into the current capabilities present in the Dutch house building system to adopt both methods. This overview can influence the recommendations to implement these methods in an effective and feasible way and should therefore be included.

Furthermore, this researched outlined the importance of the simultaneous and gradual development of the biobased production chain. Future research should focus on the creation of knowledge of future demand of biobased building materials in the Dutch house building system. Insights into the future demand prospects are scarce and therefore future research should focus on the creation of this information. This information can aid the agricultural, processing and building industry to simultaneously develop their capabilities to prevent discrepancies in the chain. Also, this research found that the local governments (provincial and municipal) posses considerable influence to alter the landscape in their respective regions. Future research should focus on how this influence can be utilised in the most effective and feasible way to improve the sustainability of the house building system in the respective regions.

6. Conclusion

This research outlined the current hindering and stimulating factors present in the Dutch house building system. In this chapter, the main research question will be answered. Thereafter, this chapter will answer the intervention question, recommendations for practice, and research limitations.

6.1 Adopting biobased building materials

This chapter answers the following main research question:

What are the current barriers and opportunities for the adoption of biobased building materials in the Dutch house building system?

To answer the main research question the current position of biobased building materials in the current Dutch house building system was analysed. The current developments on the landscape, regime and niche revealed the transition to be in the second phase of the technological transition. The developments further indicate the transition to be at the end of the second phase indicating that it will transition to the third phase in the near future. However, there are still hindering factors in place which negatively influence the adoption process of biobased building materials in the Dutch house building system. There are three main barriers hindering the adoption processes of biobased building materials present in the landscape. First, the different interpretation of the European legislation by the Dutch national governments creates a complicated regulatory environment in the Dutch biobased building material market. This complicated the entering process of foreign biobased initiatives which isolates the Dutch market. The national government possesses the opportunity to aid the development of a robust biobased building material market by interpreting the European legislation more similarly to other member states. This simplifies the regulatory environment among other member states which result in an easier entering process for foreign biobased initiatives.

There is an apparent lack of long-term unambiguous policy from the national government. In addition, the national government displays a pattern of altering the timeline and requirements of policies which negatively impacted the credibility of existing policies. This creates uncertainty within the Dutch house building system since they rely on the timeline and requirements of these policies to dictate the scheduling of their investments. Furthermore, it created an environment where the Dutch house building system is incentivised to delay the transition of their building processes. To remove this incentive the credibility of national policies needs to be improved. This can be achieved by better enshrining timeline and climate ambitions for the building sector in more durable legislation to decrease the likelihood that these ambitions will be altered. This incentivises the Dutch house building system to develop competitive and more sustainable building processes since passively waiting will result in a future loss of competitiveness. Lastly, there is an inherent political and institutional lock-in mechanism at play regarding the existing MPG regulation. There are several in-built biases present in the current assumptions and calculation method of the MPG that favour traditional building materials. The national government possesses the opportunity to alter the current MPG regulations to remove the current biases towards traditional building materials.

The introduction of new national policies generally takes multiple years to take into effect. This creates an opportunity for provincial and municipal governments to introduce more ambitious policies in their respective regions. These local policies are more versatile, better suited to the respective regions and can be implemented significantly faster than national policies. However, it is important to align these new local policies between municipalities and provinces

to prevent creating an unnecessary complicated regulation environment for the Dutch house building system. Nonetheless, the introduction of more ambitious local policies regarding spatial developments, positively influences the adoption process of biobased building materials in local house building systems.

The long-term dominant use of traditional building materials has resulted in high levels of technical knowledge when designing, manufacturing and installing tradition building materials in the Dutch house building system. This long time use grants traditional building materials several benefits over their biobased counterparts due to decades of incremental innovations. Biobased building materials are currently more expensive, posses a less efficient and reliable supply chain while providing similar performance compared to their traditional counterparts. Furthermore, the current minimal circularity rating dictated by the MPG can be relatively easily achieved using mainly traditional building materials. As a result, the Dutch house building system remains hesitant to transition towards biobased building materials due to the high associated risks and a lack of incentive by the current regulations. This research revealed two methods that reduces the financial risk when transitioning from traditional to biobased building materials namely the hybrid construction form and flex dwellings. Both methods allow the current Dutch house building system to gradually introduce more biobased building materials into their building process. This reduces the financial risks since building companies are not required to alter their building process all at once. Furthermore, the gradual nature of both methods also allows companies to better coordinate the speed of their transition based on the development of future building regulations. Housing corporations and local governments can function as launching customers which allows for the further development of the biobased building material niche.

However, the success of the transition of the current Dutch house building system to biobased building materials heavily relies on the further development of the biobased building material niche. This development is currently hindered by limited financial opportunities for biobased building material companies. This is attributed to the high associated risks when investing in biobased building materials. Increasing the demand, by using hybrid flex construction and flex dwellings, decreases these risks and subsequently increases the willingness of financial actors to invest in the biobased building material niche. This is crucial since this allows biobased building material companies to invest in obtaining the proper certifications and providing the NMD with verified data. The further development of the biobased production chain is crucial to facilitate this increased demand. This is currently hindered by a development stalemate between the three links of the chain. This slows the development of the supporting industries and subsequently the biobased building material niche. The current efforts by the national government in setting up these chains proves to be insufficient. The creation of private intermediary companies can function as an additional development path of biobased production chains. To simplify the creation of biobased production chains an insight into the future demand of biobased building materials proves vital. Housing corporations and building companies can aid in this process by mapping their future demand for biobased materials. This process can also be supported by the creation of a provincial covenant. To conclude, while there are still several barriers to overcome before biobased building materials can be used on a widespread scale. This research revealed the potential of biobased building materials to significantly increase the sustainability of the Dutch house building system while also ensuring a stable and sufficient production rate.

6.2 Recommendations for practice

Building with biobased building materials reduces the embodied energy present in new housing developments. More importantly, it provides the possibility to construct new homes without omitting nitrogen. This can provide the province of Gelderland with significantly more usable land for spatial developments near natura 2000 areas. Therefore, expediting the adoption of biobased building materials in the province of Gelderland will be crucial to secure a stable housing production in the future. This section answers the following intervention question: '*How can the adoption process of biobased building materials be expedited in the house building system in the province of Gelderland?'* Furthermore, this section provides advice to provincial and municipal policy officers as well as recommendations for the house building system in the province of Gelderland.

Local governments

The tightening of the MPG is happening too slowly in addition to the fact that there are several in-built biased present in the current regulations. Local governments can help expedite the adoption process of biobased building materials in their respective regions by implementing more ambitious stimulating policies. Municipal governments can implement more ambitious policies to expedite the adoption of biobased building materials in the local house building system. This proves to be an effective method since it creates a direct incentive for the local house building system to use these materials. However, to increase the effectiveness of this policy, municipal policy officers should take two important factors into consideration. First, it is important that the municipalities coordinate their policies in a similar way to other municipalities in the province. This ensures that the regulation environment within the province does not become splintered with various policies arising in all municipalities. Secondly, the municipalities should analyse their local house building systems to gain an insight into the current possibilities of local building companies to comply with stricter regulations. This insight prevents the municipality from adopting too ambitious circularity ambitions and subsequent side lining of significant parts of their house production capabilities. The policy 'Het Nieuwe Normaal 1.0' emerged as a promising method to reduce both negative effects. First, this policy has been adopted on a larger scale by over 80 municipalities which aids in coordinating municipal policies to align with each other. Secondly, this policy does not calculate a singular end score like the MPG but rather rates multiple indicators which provides a more detailed insight into the circularity of a spatial development. This allows a tailored approach for each spatial development which prevents the sidelining of significant parts of the local house building system.

The provincial government of Gelderland can positively influence the adoption process of biobased building materials in their provincial house building system. First, the province can increase its assistance to the municipalities in the process of adopting new policies. The province can create and distribute technical and legal information for municipalities to increase the experience and know-how of municipal policy officials. This is especially relevant for smaller municipalities where one policy official is responsible for multiple departments. Secondly, the province can aid the coordination of municipal policies by the creation of a covenant since it unifies the regulatory environment within the province. This creates clarity for the local house building system since it provides one singular circularity framework which they will operate in. A covenant also includes private actors who provide valuable information which results in more effective and feasible policies. While a covenant may not be legally binding, it does solidify the willingness of the provincial and local governments to make their

local house building systems more sustainable. Lastly, the province of Gelderland can also stimulate the development of biobased production chains. This can be done by expanding their collaboration with building balance as well as implementing a stimulating agricultural policy. Furthermore, the province can identify suitable locations for processing industries and invest in the preparation of these locations to make the introduction of processing plants easier. This can be done by providing subsidies to the municipalities where these locations reside.

The house building system in the province of Gelderland

The house building system in Gelderland should take not of the delicate situation in which it currently resides. While the current system complies with national policies, new and more strict regulations are being drawn up. Also, the additional regulations for new developments near Natura 2000 areas cause additional costs and delays. The house building system should therefore view biobased building materials as a method which aids their future business processes. While adopting biobased building materials early possesses more financial risks. The house building system in Gelderland can also see it as an opportunity. By adopting biobased building materials early, the house building system of Gelderland will be better prepared when new and stricter regulations will be implemented. This provides an early advantage compared to other more traditional house building systems. To maximise the advantages, the house building system in Gelderland should map their future demands for biobased building materials. Also, the house building system should stand willingly to collaborate with local governments to create a covenant. This reduces the financial risks and can simplify the regulatory environment within the province.

6.3 Research limitations and reflection

The Dutch house building system has several unique characteristics which makes generalising the results to other house building systems in other countries difficult. As a result, the direct transferability of the results of this research in other building systems is limited. However, the results of this research can be generalised to some limited extent. The results of this research, in conjunction with similar studies in other countries, can contribute to the creation of a general innovation adoption process framework for developed house building systems. The data collection of this research was limited to 11 interviews and 4 policy documents. As a result, some actor groups were represented by only one interviewee which influences the plausibility of the results to some extent. While the use of semi-structured interviews allowed the researcher to gain more in-depth information. The researcher may be biased which could influence the narrative and method of questioning which influences the data collection process. Also, the MLP framework places significant responsibility on the researcher to demarcate the research subject and to operationalise key concepts. Three pilot interviews were conducted before the start of this research which improved the demarcation process as well as the operationalisation of key concepts. The inclusion of deductive codes also placed significant responsibility on the researcher. Therefore, this may result in difficulties when replicating this research which does reduce the reliability of this research. However, this was deemed necessary to extract the relevant pieces of information from all the gathered primary data.

During the research process I developed myself as a researcher. While I was at first intimidated by the size of a masters' thesis. During my interviews I quickly learned that the larger size was beneficial to my research since it allowed me to delve deeper into the

concrete workings within the Dutch house building system. At the start of my research, I was trying to find the perfect research set up. I gradually learned rather than focussing on the perfect research set up. It is more valuable to focus on why I made certain research choices.

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8. Appendix

Appendix 1 Interview guide (English)

Interview Guide

Name:

Organization:

Function:

Date and time:

Interview number:

Introduction

Dear (Name of interviewee), first of all I would like to thank you for participating in this interview. My name is Koen Wentholt and I am currently doing the master's degree in Land and Real Estate development at Radboud University in Nijmegen. For my master's thesis I am investigating how the usage of biobased building materials can be scaled up in the construction sector in the province of Gelderland. The aim of this research is to gain insight into the possibilities and barriers of this process, thereby gaining more insight into how the construction sector in Gelderland can become more sustainable. I will be taking notes during this interview however, for completeness it would help me to record the audio of the interview. This way I can make a transcription afterwards to ensure that no important matters are overlooked. The recording will only be used in transcribing this interview. You can tell me at any time that you want to stop the recording? Are you okay with that? Then I will start the recording now. The interview will last approximately 45 minutes to one hour. If you no longer wish to participate in this interview, you can indicate this at any time.

Could you briefly tell us something about yourself, such as education, position and your company?

Interview questions

1. How would you describe the current market for biobased building materials?; Also ask to the size of the market

2. Which actors, in your opinion, play an important role in the transition to making the construction sector in the Netherlands more sustainable?

3. What role do you think the national government plays in the scaling-up process of bio-based building materials?

    a. And how do you see the role of the Province of Gelderland?

4. What do you think is the biggest barrier to scaling up the biobased construction industry in Gelderland?

5. What role do you think the traditional construction sector plays in the scaling-up process of bio-based building materials?

6. What role do banks and insurers play in accelerating the transition to biobased building materials?

7. What do you think would be needed to accelerate the uptake of biobased building materials in Gelderland?

8. Are there any things you want to add in addition to the questions I have asked?

These were my research questions. I would like to thank you very much for your contribution to my research. If I had another question, could I contact you if I had a follow-up question at a later time? This also applies the other way around, if you have any questions or would like to make an addition, please email me at any time. Finally, would you like the result to be emailed to you after the completion of my research?