Sveriges lantbruksuniversitet
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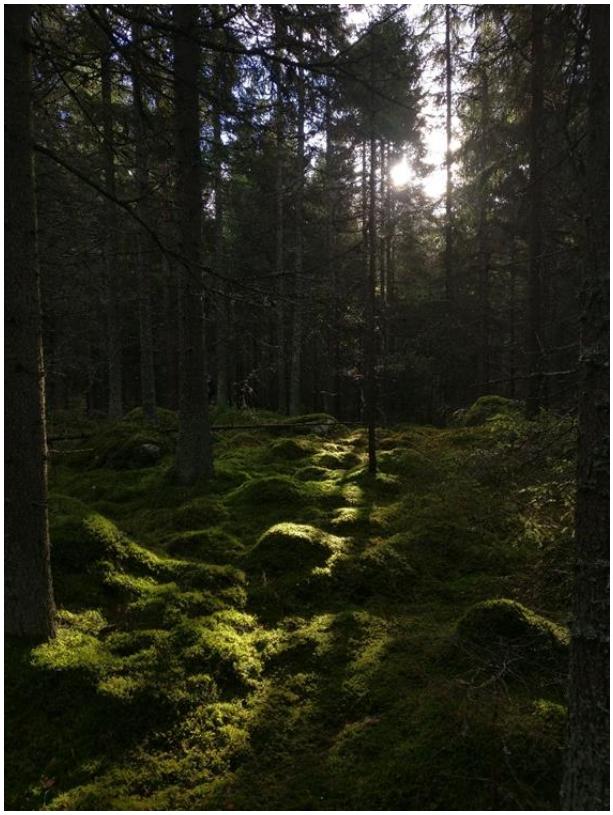
Department of Forest Economics

Forest-based bioeconomy - to be or not to be? – a socio-technical transition

Skogsbaserad bioekonomi - att vara eller inte vara? – en socio-teknisk övergång

Carolina Berg Rustas & Emil Nagy



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Abstract

In this study, social acceptance of forest-based bioeconomy and primarily wooden multi-story buildings was examined. This study is a pilot study. Earlier studies have examined different stakeholder groups' perceptions of the bioeconomy, but one group that has not been examined thoroughly is the public. However, citizens perceptions and knowledge about bioeconomy is vital if a transition towards bioeconomy should take place, which is why this important stakeholder group need to be further examined.

This study is aimed to identify hindering and enabling factors for social acceptance of a low-carbon transition in Sweden. The low-carbon transition is represented by a forest-based bioeconomy and wooden multi-story buildings. With the help of a theoretical framework that analyses innovations and social acceptance, several hindering and enabling factors for a low-carbon transition were found within the studied population. The study uses primary data from 204 respondents who answered a survey, and secondary data from scientific studies, policy documents, and official statistics.

This study concludes that there was a lack of knowledge in the population regarding forest-based bioeconomy. The knowledge about wooden multi-story buildings was slightly higher. The population, in general, was positive towards wooden multi-story buildings. Among the respondents, the generally positive attitude towards forest-based bioeconomy and the knowledge about wooden multi-story buildings can be seen as enabling factors for social acceptance of a forest-based bioeconomy. An example of a hindering factor was the limited knowledge about the full meaning of the forest-based bioeconomy.

This study should be seen as a snapshot of the studied respondents during the specific days the study was carried out, and it can be discussed if generalisations can be made. However, it provides valuable information about current perceptions and knowledge of citizens, which can guide future studies.

Key words: *enabling factors, hindering factors, low carbon transition, public perception, wooden multi-story buildings, wooden multi-storey buildings*

Sammanfattning

I den här studien har social acceptans av skogsbaserad bioekonomi och i synnerhet flervåningshus med stomme i trä undersökts. Denna studie kan ses som en förstudie till vidare undersökningar där mer generella slutsatser skulle kunna dras. Tidigare studier har undersökt olika intressegruppers uppfattningar om bioekonomi, men en grupp som ännu inte undersökts är allmänheten. Att inkludera vanliga medborgare i samtalet kring bioekonomi pekas ut som en viktig faktor för acceptans av förändring dock har gruppen medborgare i liten utsträckning blivit undersökt vad gällande deras inställning och kunskap till bioekonomi.

Syftet med denna studie var att identifiera möjliggörande och hindrande faktorer för social acceptans av en lågkoldioxid-övergång i Sverige. I studien representeras lågkoldioxid-övergången av skogsbaserad bioekonomi samt höghus med stomme av trä. Med hjälp av ett teoretiskt ramverk som analyserar innovationer och social acceptans har ett antal hindrande och möjliggörande faktorer för en lågkoloxid-övergång identifierats hos den studerade populationen samt i samhället i stort. Studien bygger på primärdata från en enkätundersökning som besvarades av 204 respondenter, samt sekundärdata i form utav vetenskapliga studier, policydokument och officiell statistik.

I studien dras slutsatsen att i den undersökta gruppen respondenter i hög grad inte visste vad skogsbaserad bioekonomi var samt att kunskapen om flervåningshus i trä var något högre och att man generellt var positivt inställd till flervåningshus i trä. Den generellt positiva inställningen till skogsbaserad bioekonomi och flervåningshus med stomme i trä kan ses som ett exempel på en möjliggörande faktor. Exempel på hindrande faktorer är dålig kunskap om begreppet skogsbaserad bioekonomi.

Denna studie bör ses som en ögonblicksbild av en de studerade respondenterna under de specifika dagarna studien pågick och ingen generalisering kan göras men studien kan ligga till grund för vidare forskning och ge en fingervisning av vad som skulle kunna vara möjliggörande och hindrande faktorer för att utveckla bioekonomin.

Nyckelord: *bioekonomi, flervåningshus i trä, hindrande faktorer, möjliggörande faktorer, skogsbaserad bioekonomi, social acceptans, socio-teknisk övergång*

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Secondly, we would like to thank the employees at IKEA who supported us and made our data collection possible. Without their superb service, our data collection would have been much harder!

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Fourthly, we are also very grateful to the respondents of our survey who generously gave us approximately seven and a half minutes of their time to answer it.

Lastly, but not least, we want to thank our outstanding supervisor Cecilia Mark-Herbert, who has helped us immensely during the process. Few teachers are as dedicated as her, and she sure deserves all the praise she gets.

Thank you all!

Carolina Berg Rustas & Emil Nagy

Abbreviations

Abbreviation	*Explanation*	*First introduced on page*
BE	Bioeconomy	*1*
Boverket	Swedish National Board of Housing, Building and Planning	*38*
EFI	European Forest Institute	*7*
ENGO:s	Environmental non-governmental organizations	*3*
EU	the European Union	*2*
FBB	Forest-based bioeconomy	*2*
FORMAS	the Swedish Research Council for the Environment, Agricultural Sciences and Spatial Planning	*14*
GDPR	The General Data Protection Regulation	*13*
IEA	International Energy Agency	*2*
LCA	Life cycle analysis	*32*
LCT	Low carbon transition	*1*
MLP	Multi-level perspective	*1*
OECD	the Organisation for Economic Co-operation and Development	*14*
R&D	Research and development	*22*
SA	Social acceptance	*3*
SEK	Swedish Crowns	*2*
SLU	Swedish University of Agricultural Sciences	*9*
ST-configurations	Socio-technical configurations	*19*
ST-landscape	Socio-technical landscape	*21*
ST-regime	Socio-technical regime	*7*
ST-systems	Socio-technical systems	*19*
ST-transitions	Socio-technical transitions	*1*
SWFI	Swedish Federation of Wood and Furniture Industry	
PerForm	Perceiving the Forest Based Bioeconomy	*7*
UNEP	United Nations Environmental Program	*2*
WBCSD	World Business Council for Sustainable Development	*4*
WMBs	Wooden multi-story buildings with a mostly wooden frame	*2*

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1 Introduction

This section identifies and presents the problem in the problem background. Furthermore, the aim and the delimitations of the study are described.

1.1 Problem background

During the last decades, there has been a fast acceleration in the use of fossil fuels and greenhouse gas emissions in the world, e.g. carbon dioxide (Intergovernmental Panel on Climate Change, 2018). The emissions contribute to the rapid increase in the world's average temperature. If the current increase in average temperature continues, the world's average temperature caused by anthropogenic activities (based on pre-industrial levels) will rise by 1,5 degrees Celsius between the years 2030 and 2052 (Intergovernmental Panel on Climate Change, 2018, p. 8).

Science, societies and politicians around the world have now agreed that human activities contribute to global warming and that actions need to be taken. One example is the Paris Agreement, which was adopted by consensus in 2015 and which was ratified the 4th of November in 2016 (Nationalencyklopedin 2019b). The Paris Agreement stresses the importance of low carbon solutions (UNFCCC, 2019) and to fulfil the goals of the Paris Agreement substantial low carbon transitions (**LCTs**) have to take place (Roberts *et al*. 2018).

1.1.1 Low carbon transitions

LCTs can be explained as substantial changes in the systems that serve society so that these systems have less impact on the climate. Such systems can, for example, be transportation, energy, agriculture and housing. LCTs in these systems can include increased energy efficiency and, or the use of fewer resources or renewable resources (Geels *et al*. 2016a). The feasibility of LCTs can be studied by applying the socio-technical transition (**ST-transition**) theory. According to Geels *et al*. (2016), the ST-transition theory can be used:

"...to assess the socio-political feasibility and social acceptance and legitimacy of various low-carbon options, by analysing the interpretations, strategies and resources of different social groups" (Geels et al., 2016, p. 580).

The ST-transition theory provides information about how actors influence the implementation of specific low-carbon options. The influence can either be hindering or stimulating and is understood through the multi-level perspective (**MLP**) of the ST-transition theory. Such studies typically analyse developments in the recent past to help identify drivers and barriers of low-carbon innovations and transition pathways in the present (Geels *et al*., 2016, p. 580). Examples of areas where LCTs have been studied using the MLP include electricity systems (Verbong & Geels 2007, 2010), energy systems (Matschoss & Heiskanen 2018), transportation (Reichenbach & Puhe 2018) and the building sector (Smith 2007; Gibbs & O'Neill 2014).

1.1.2 Bioeconomy

One example of an LCT that has not previously been studied using the MLP is bioeconomy (**BE**) or bio-based economy. In BE renewable and bio-based materials with less climate impact are used instead of fossil-based materials, to reduce the greenhouse gas effect (Priefer *et al*. 2017). The European Union (**EU**) regards BE as one important LCT:s. However, in order to enable a transition to BE within the EU, innovation and research is needed (European Commission 2018a). So far, the EU has invested €3,85 billion in research and innovation regarding BE through the research and innovation programme Horizon 2020, and even higher investments are planned (European Commission 2013, 2018a).

Similar to the EU, Sweden also sees BE as a solution to climate change challenges. In Sweden, BE is promoted by policymakers through the funding of research programmes and development of implementation strategies (Government Offices of Sweden 2018b; c). Since forests cover approximately 69% of Sweden's land surface (Nilsson & Cory 2018 p. 48) and the forest industry offers approximately 120 000 jobs and an export value of 132 billion Swedish crowns (**SEK**) (Swedish Forest Industries Federation 2019), much attention is given to forest-based bioeconomy (**FBB**) in Sweden. As in the EU, innovation is essential for the Swedish BE, which takes place both within the industry as well as through research platforms (BioInnovation 2018; Stora Enso 2019). One example of such an innovation in Sweden are multi-story buildings with a mostly wooden frame (**WMBs**), which differs from the dominant steel and concrete construction techniques.

1.1.3 The system of housing in Sweden

As mentioned in section 1.1.1, LCTs are substantial changes in the systems that serve society, so that these systems have less impact on the climate. One such system is housing. In Sweden, the building and real estate sector stands for approximately 21% of the total greenhouse gas emissions. Of these, 21%, 40% are directly connected to newly built housing and renovation, while the rest is connected to estate management, primarily heating. Even though the total emissions from the building and real estate sector have decreased during the period 1993-2016, the part that originates from the construction of new housing and renovation remains constant (National Board of Housing, Building and Planning 2019). Concerning carbon emissions, this indicates that there is room for improvement in the construction sector.

According to the International Energy Agency (**IEA**) and the United Nations Environmental Program (**UNEP**), 28% of the CO2 emissions that are related to buildings originate from the use of material. Most of the emissions coming from the material used in buildings are a result of cement and steel manufacturing, while glass, insulation and aluminium also contribute (International Energy Agency & United Nations Environment Programme 2018 p. 43). The IEA suggests that a change in material towards bio-based materials has the potential to reduce the carbon emissions originating from the material-use for buildings (IEA, 2018, p. 46). That bio-based material has the potential to reduce carbon emissions is also supported scientifically as several studies have indicated that wood-based products have the possibility to decrease greenhouse gas emissions and energy use compared to other construction materials (Perez-Garcia *et al*. 2005; Dodoo *et al*. 2012; Gong *et al*. 2012; Nässén *et al*. 2012).

As 90% of the newly built single-family houses in Sweden are built of wood (Hemström *et al*. 2012), the effect of increased use of wood as a construction material in single-family housing would be small. However, multi-story housing is slightly different, as approximately 85-90% of the multi-story buildings in Sweden are built with a concrete or steel frame (Statistics Sweden 2019b). The remaining 10-15% of the multi-story buildings in Sweden are built with a wooden frame (Statistics Sweden 2019b), which is a relatively new technique in the multi-story buildings sector serving as an alternative to the dominant steel and concrete techniques. Therefore, it seems like an LCT can take place in the system of housing in Sweden, primarily by adopting the innovation of WMBs to a more significant degree.

1.2 Problem

In this section, the theoretical and empirical problem is presented. The theoretical problem is presented in section 1.2.1, where the difference between historical transitions and LCTs is explained. The empirical problem is presented in section 1.2.2, where the risk of failure in innovation is discussed.

1.2.1 Difference between historical transitions and low carbon transitions

Early work on ST-transitions used the ST-transition theory and the MLP on historical case studies such as the transition from sailing ships to steamships in the 19th century (Geels 2002), or the transition from horse-drawn carriages to automobiles in America in the late 19th and early 20th century (Geels, 2005). These historical transitions emerged during long periods and were driven by private economic benefits that originated from the creation and implementation of new technologies and practices (Pearson & Foxon 2012).

Unlike the historical transitions, LCTs are not driven by private economic benefits. These are instead problem-oriented (Pearson & Foxon, 2012) and purposive (Smith *et al*. 2005). The goal with LCTs is to mitigate the harm on the climate, which is a societal good (Pearson & Foxon, 2012). Private actors, therefore, have limited incentives to engage in LCTs, which make low-carbon transitions different from historical transition (Geels *et al*. 2017), even though some argue that the need for LCTs and sustainability can be turned into an opportunity for private actors (Bourdeau 1999; Belz & Peattie 2012). Albeit, Geels *et al*. (2017) argue that because of the limited incentives for private actors to engage in LCTs, public policy is needed to create economic frame conditions that support low carbon innovations to be developed and implemented successfully in the market. Examples of policy instruments are regulations, taxes, subsidies or standards (Geels *et al*., 2017).

However, governments tend to be reluctant to implement such low carbon policies as it is viewed as "bad politics" and create a risk of public backlash or bad public opinion figures (Ockwell *et al*. 2009). One such public backlash can be illustrated by the yellow vests movement currently taking place in France and other parts of the EU (Rubin & Sengupta, 2018). Despite this, there are examples of low carbon policies that have been politically neutral or positive (Ockwell *et al*., 2009) and the key to success for policymakers when implementing climate change mitigation policies is to gain widespread political support from citizens (Giddens 2009).

As public policies are crucial for enabling LCTs and widespread public support is needed to enforce these policies, there is a need to investigate the public opinion on LCTs. In the case of Sweden, one possible LCT is the transition towards an FBB and several scholars highlight the importance of citizens in this transition. Mustalahti (2018) states that citizens need to be included if a transition towards BE is to be successful. A similar view is held by Peltomaa (2018), who argue that the concept and implementation of BE have to be legitimised by citizens in order to be realised. Hodge *et al*. (2017) have studied how different forestry stakeholders; forest owners, forest industry and environmental non-governmental organisations (**ENGO:s**) in Sweden perceive the concept of BE. However, how citizens perceive the FBB has not yet been studied thoroughly in Sweden, nor the EU. There is, therefore, a lack of knowledge about social acceptance (**SA**) and perceptions of FBB. Whether the public perceptions are enabling or hindering factors for implementing the LCT of FBB in Sweden today is also unknown.

1.2.2 Innovation and the risk of failure

As mentioned in section 1.1.2, governments and companies in the EU invest vast resources in BE innovation to enable an LCT. For a low carbon innovation to be successful, companies need to have the ability to establish it on the global mainstream market, rather than in small niche markets (Pinkse & Kolk 2010). However, even though significant investments in innovation are made, there is no guarantee of market success. Studies have shown that product innovation failure rates are approximately 50-90 per cent (Heidenreich & Spieth, 2013, p. 1), indicating that most innovations are never widely adopted in the market.

According to Heidenreich & Spieth (2013), the main reason why new products are not quickly adopted in the market is that customers often show resistance to change or have product-specific barriers. Moreover, Geels, (2011) states that most sustainable solutions are at a disadvantage from the mainstream technology, as sustainable solutions often do not offer a more attractive price or quality. Instead of offering the user any apparent benefits, it addresses a collective good (Geels, 2011), creating few incentives for end consumers to invest in the innovation. Similarly, the World Business Council for Sustainable Development (2008) (**WBCSD**) suggests that even though consumers are increasingly aware of sustainability and willing to act, there are several barriers for consumers to adopt a more sustainable consumption behaviour.

Traditionally, the forest products market has focused less on the behaviour of end consumers and more on the intermediary consumer such as retailers, wholesalers, distributors and secondary manufacturers (Anderson *et al*. 2005). However, product demand on the intermediate level is derived from a demand from the end consumer (Anderson *et al*. 2005) and the consumers' behaviours and perceptions about an innovation, therefore, have the potential to influence its rate of adoption in the market profoundly. However, how end consumers perceive WMBs, which is an innovation that can enable an LCT within the housing system in Sweden, has not yet been studied. Neither has it been studied if the SA and perceptions of end consumers are enabling or hindering factors for establishing WMBs as the dominant technique within the multi-story construction sector in Sweden.

1.3 Aim

This study aims to identify enabling and hindering factors connected to the social acceptance of a low carbon transition within a group of Swedish citizens. The transition towards a forest-based bioeconomy in the housing system is used as a case study. Hence, multi-story construction with a mostly wooden frame is used as an example of an innovation representing forest-based bioeconomy in the system of housing. As citizens and customers are essential stakeholder groups that can both hinder and promote low carbon transitions, the focus is put on how they perceive the forest-based bioeconomy and the innovation of multi-story buildings with a mostly wooden frame. Public perceptions are in this study used to analyse the social acceptance of these concepts.

The aim is fulfilled by answering the following research questions:

- How do Swedish citizens perceive the low-carbon transition of forest-based bioeconomy?
- How do Swedish consumers perceive the niche innovation of multi-story buildings with a mostly wooden frame in comparison to the dominant socio-technical regime of concrete and steel constructions in Sweden?

1.4 Delimitations

The MLP theory tries to explain ST-transitions through analysing the dominant regime, the landscape and the niches of an ST-system. This study focuses on identifying enabling and hindering factors connected to SA of an LCT and, therefore, market and user preferences will be of primary interest. Other elements of the MLP, such as science, policy, culture and technology, will be considered, albeit not as thoroughly. The same is valid for opinions and practices of other stakeholder groups than citizens and customers, which are the stakeholders of primary interest in this study.

Moreover, the study will focus on a group of Swedish citizens and consumers, limiting the geographical scope to an LCT in a Swedish context. In this study, the housing system and in particular, the multi-story construction sector will be used as an example of a part of the economy where a transition towards FBB can take place. Multi-story buildings with a mostly wooden frame are used as an example of innovation for several reasons:

- housing fulfils several of the basic human needs as pointed out by Maslow (1943)
- there is a lack of housing and a need to accelerate the building of new housing in Sweden (National Board of Housing, Building and Planning 2018b) and;
- the building and real estate sector contributes substantially to greenhouse gas emissions in Sweden. While a decrease in emissions from the heating of buildings has taken place, the emissions from the building and restoration of houses remain constant (National Board of Housing, Building and Planning 2019).

Multi-story buildings for both residential and commercial use are considered as it is sometimes difficult to distinguish for which use a building is intended.

2 Method

This chapter provides arguments and choices made by the authors concerning the methods used in this thesis. The chapter begins with describing the research approach, continuing with how data was collected, the choice of unit of analysis, and how the data was collected. The chapter ends with the method of analysis, quality assurance and ethical considerations.

2.1 Research approach

Robson & McCartan (2016) describe two systems concerning real-world research, open systems and closed systems. Closed systems function in a closed environment in a laboratory and open systems function outside the laboratory. In the open system of real-world research, the configurations of structures and processes are continually changing, making definite prediction impossible. This study was performed in the open system, as it is influenced by the environment, which is made up of different types of humans, inputs, knowledge, languages, nationalities etcetera. Therefore, this study cannot be, as Robson and McCartan define a closed system, hermetically sealed from external influences.

A study can be inductive, deductive or abductive. An inductive study moves from the empirical material to the formation of theory, whereas a deductive study moves from theory to empirical observations. In an abductive study, the researcher alternates between theory and empirics (Robson & McCartan, 2016). This study has an inductive approach as it moves from observations to theory.

To articulate which method and study design is needed for this thesis, we must go back to the aim of this study. Since this study aims to study a contemporary real-life phenomenon, the concept of a case study can be applied (Yin, 2009; Robson & McCartan, 2016).

Yin (2009) and Robson & McCartan (2016, p. 150) suggest that a case study *"... is a strategy for doing research which involves an empirical investigation of a particular contemporary phenomenon within its real-life context using multiple sources of evidence"*. The case study should not be perceived as the method but rather a strategy or approach (Yin, 2009).

The case study approach was chosen in this thesis because the subject studied was found to fit the twofold definition formulated by Yin (2009, p. 18) and the description by Robson & McCartan (2016, p. 80) of what a typical case study should entail, in summary:

- developed detailed, intensive knowledge about a single case of a situation, individual or group of interest or concern
- study the case in its context
- collection of information via a range of data collection techniques

In this study, the points made above are accounted for as follows. The focus was put on understanding the group studied. The respondents were also studied in a setting where they consume. Moreover, the case was studied both through a survey but also with desk-based research to provide valid background information to describe the case better.

In this part, choices of research approaches have been argued for; the next part describes the unit of analysis of this thesis.

2.2 Choice of unit of analysis

The unit of analysis in this study was the conditions for change in the socio-technical regime (**ST-regime**) of multi-story buildings in Sweden, as this represents the feasibility of a low-carbon transition. In this case study, the LCT studied is the implementation of FBB within the housing system in Sweden. The context chosen for the survey was the IKEA warehouse in Uppsala, Sweden. IKEA was chosen as the survey location because IKEA offers its customers a variety of forest-based products (among else). The warehouse in Uppsala was also elected because of its availability to the authors.

2.3 Strategy of data collection

This study was initiated by a European research project called "Perceiving the Forest-Based Bioeconomy" (PerForm). PerForm was financed by the European Forest Institute (EFI) and executed in eight different European countries (Austria, Finland, Germany, France, Sweden, Italy, Slovakia and Russia). The PerForm project consisted of five different tasks. This study was part of the task where urban consumers' perceptions of FBB were studied. In this part of the project, master students in the eight different European countries similarly collected data, using the same survey and questions. It should be remembered throughout this study that the data collected is a part of a larger research project with a data set from several European countries.

However, this study had a quantitative approach to collect the perceptions about FBB and WMBs of Swedish consumers. According to Robson & McCartan (2016, p. 19), quantitative social research has some typical features. These features and how they should be applied in quantitative social research, according to Robson and McCartan (2016) can be seen in Table 1 below. Table 1 also indicates how these features are accounted for in this study.

Table 1. Overview of typical features of quantitative social research according to Robson & McCartan (2016, p. 19) and how it was accounted for in this study

Some typical features of quantitative social research according to Robson & McCartan (2016, p. 19)	**How it is accounted for the typical features in this thesis**
Data has to be measurable, quantifiable, collected in number	Data was collected in numbers according to the Likert scale which is described in 2.4.2 and data was measurable and quantifiable.
Focus on what people do or say	In the survey the focus was put on how people perceive BE and WMB.
Pre-specified design and detailed in an early stage	The design was pre-specified and how the data should be collected was also pre-specified by the researchers in the PerForm-project.
Reliability and validity of the measurements are important when evaluating data	Validity and reliability are considered in this study. The importance of validity and reliability is accounted for in section 2.6.
Very specific in the description of the procedures for replication	The description of the procedures of this study is accounted for in the method chapter as well as in Appendix V to assure that this study can be replicated.
Statistical analysis	Statistical analysis has been made through descriptive statistics

Generalizability of the data	Since the data was collected at one site and retail store generalizations should be done with much caution.
Objectivity and value free position of the researcher	The authors of this thesis have during the completion of this thesis tried to be as objective as possible, but both the authors have a major in forestry, this could be considered throughout the thesis.

In Table 1 presents how the authors of this thesis have accounted for some of the typical features of a quantitative social research project by Robson and McCartan (2016). Overall this study accounts for, to a great extent, the typical features Robson and McCartan (2016) declare. The most crucial aspect to notice in Table 1 is that the data was non-generalizable and descriptive statistics were used. In the next part of this chapter, the choice of analysis is presented.

2.4 Data collection

In this part of the chapter, the sampling method, the survey, and how the data was collected are presented.

2.4.1 Sampling method

The chosen sampling method for collecting data was an intercept survey. In an intercept survey, the data is collected at a store either face-to-face or through questionnaires, which are self-administered (Anderson *et al*. 2005). Anderson *et al*. (2005) account for advantages with an intercept survey as a method. Firstly, the target population is concentrated at a store which sells the products related to the survey. Secondly, it is also possible for the researchers to make sure that the respondents belong to the target group. Thirdly, the method also offers a quick way to gather data. The disadvantages with the method are that the sample might not be representative of the whole population as the survey personnel might be biased, only focusing on a particular type of respondents. Moreover, there is a risk of the sample being geographically skewed and limited to metropolitan areas (Anderson *et al*., 2005).

In order to avoid the risk of the sample not being representative for the total population, the sample in this study is treated like a total population.

2.4.2 The survey

The survey used in this study was filled in digitally by the respondents at the IKEA-warehouse. The survey (Appendix I) was created by the researchers within the European research project PerForm. In the survey, a six-point Likert scale was used to capture variation in the perception of the consumers (1=Strongly disagree, 2=Disagree, 3=Mildly disagree, 4=Mildly agree, 5=Agree and 6=Strongly agree). The option "do not know" was not given to the respondents. Hence, the respondents were forced to answer in order to finalise the survey. However, the survey personnel were available for clarifications. The "do not know"-option was retained. Mainly because the study aimed at evaluating the respondents' perception rather than their knowledge. Uncertainty should, therefore, be reflected in people's tendency to choose more moderate options (mildly agree/mildly disagree).

The survey questionnaire can be seen as a whole in Appendix I and was, apart from information about the respondent, divided into four different subject areas:

1. how the respondent perceives multi-story buildings with a mostly wooden frame;

2. how the respondent perceives carbon storage in forests;
3. how the respondent perceives FBB and
4. voluntary free text answers on what products the respondent associate with FBB and what importance it will have in the future.

2.4.3 Execution of the survey

An English version of the survey was sent to the authors of this study by the PerForm-team. The survey was then translated to Swedish by the authors and their supervisors. The survey can be seen as a whole in both a Swedish and an English version in Appendix I. The survey was then digitised through the software Netigate, which was supplied by the Swedish University of Agricultural Sciences (SLU). Both a Swedish and an English version were created so that the survey could be answered in both languages. Also, the authors added three voluntary open-ended questions and a question about the nationality of the respondent.

The data was collected digitally through the software Netigate on the 8th and 9th of December 2018 at the IKEA warehouse in Uppsala. The data was collected during the warehouse's opening hours (10-18) in the entrance after the first moving staircase. Four laptop units with Internet connection were set up, allowing the respondents to use them independently of each other. A roll-up with the SLU-logo was placed at the survey site, and the survey personnel consisting of two master students (one female, one male) also wore clothes with the SLU-logo (see Appendix V for pictures of the survey setup).

A few respondents took the initiative to answer the survey themselves, primarily because they recognised the SLU-logo or out of curiosity of the event. The authors asked other respondents if they wanted to participate in the study. These respondents were subjectively chosen, as the survey setting provided little opportunity for applying strategic sampling techniques. However, purposely selected individuals were chosen to reach a balance between gender and age. Data collection included taking note of why respondents declined to participate, but the total number of declined invitations was not noted.

2.5 Method of analysis

In this section, the method of analysis is presented. Firstly, the type of data analysis is accounted for, and then the method of analysis for Likert-scales as well as the choice of statistical tests is brought up. Lastly, a description of the analysis and choice of survey questions is presented.

2.5.1 Type of data analysis

Robson & McCartan (2016) bring up two ways to analyse the data - confirmatory and exploratory data analysis. Confirmatory data analysis seeks to confirm hypotheses and predictions through analysis of the collected data. This type of data analysis is often connected to fixed design research and requires a high degree of pre-specification of the design and analysis of the data and its collection. It is "the mainstream approach in statistical analysis" (Robson & McCartan, 2016, p. 415).

Exploratory data analysis, on the other hand, focuses more on displaying data diagrammatically and visualising it. It can be used by researchers to conclude relationships in the dataset that the study was not designed or intended to find, after the data collection. Exploratory data analysis is more connected to flexible design research and can be used "to see what has been found and to help direct later stages of data collection" (Robson & McCartan, 2016, p. 414).

The PerForm research group created the survey used in this study and designed to explore the field of consumer understandings and communicated behaviour. The data is, therefore, analysed in an exploratory way. Arguments for the approach can be made with an understanding of the subject of this thesis rarely having been studied previously. Therefore, exploratory, descriptive data analysis is used, primarily in the form of frequency distribution bar charts.

2.5.2 Analysis of the Likert scale

Likert scales are widely discussed (Carifio & Perla, 2008; Harpe, 2015). The Likert scale is an ordinal scale with several points, where the respondents' rate to which degree they agree or disagree with each statement. The points on the scale have a specific order to each other, but the distance between the points cannot be measured. Therefore, the distance between different points on the scale (strongly disagree-disagree in comparison to disagree-mildly disagree) might not be equal over the whole scale (Sullivan & Artino 2013).

Because of the uncertainty of the distance between the points on the scale, scholars discuss whether it is appropriate to use means and parametric tests to analyse Likert scale data since this type of statistics is designed for interval data (Sullivan & Artino, 2013). The alternative is to use non-parametric tests and medians, which is acceptable to use for ordinal, interval or ratio data (Harpe, 2015). Despite this, Norman (2010) and other scholars Harpe (2015) argue that because of its robustness, parametric tests can be used to analyse normally distributed Likert data. Similarly, Sullivan and Artino (2013) argue that both medians and means can be used to describe the data. However, the data has to be normally distributed if means are to be used. As an alternative, frequency distributions of responses is also possible (Artino & Sullivan, 2013).

For a sample to be generalised, it has to be randomly selected (Robson & McCartan, 2016). If the sample is not randomly selected, it is not possible to know whether the findings are representative of the whole population (Robson & McCartan, 2016, p. 281).

The respondents of the survey were treated as a total population. Hence, no parametric or non-parametric tests were done during the analysis. Moreover, the data of this study were not normally distributed, so means are not used in the analysis. Medians were not used either as the analysis was exploratory, and the primary interest of this study was to capture the whole variation within the population. Frequency distribution tables and figures were used to present the results of the study and illustrate the whole variation within the population, as advised by Artino & Sullivan (2013).

2.5.3 Choice of survey questions

The survey used in this study was created by the PerForm-team and is presented in Appendix I. However, not all questions of the survey were used in this study, as some of the questions were not relevant to answer the aim. Firstly, one of the questions concerning how forests store carbon (question 11 of Appendix I) was used. Secondly, the questions about how the respondents perceive FBB followed (question 16-26 of Appendix I). Lastly, the questions focusing on the respondents' perceptions about wooden multi-story buildings in comparison to steel and concrete ones (question 1-10 of Appendix I) were included in the analysis. The questions are presented in a different order than they were presented to the respondents, to fit the theoretical framework.

2.5.4 Description of the analysis

The analysis was carried out using the statistical software programme SPSS. The data were imported into SPSS as an SPSS-file. As the data was imported directly from the software used to gather the data, no additional data entry by the authors of this study was needed, which minimised the possibility of entry mistakes.

Before the data was analysed, incomplete answers (n=22) were removed. Some of the incomplete answers were test-answers made to ensure the functionality of the survey software. The rest of the incomplete answers were from respondents that walked away from the survey before it was finished or did not manage to fill the survey out due to technical issues. SPSS was then used to create age categories and to divide the respondents into categories based on familiarity and understanding of key concepts presented in chapter five in this study. A further description of how that categorisation was made is available in chapter five.

Frequency distribution tables were then calculated for each question using the SPSS software. The information in these tables was then added into the Excel software and used to compute the frequency distribution bar charts presented for each question in chapter five. A cross-tabulation analysis was also done in SPSS for all of the questions presented as bar charts. The aim was to find differences in frequency distribution among the respondents that were familiar with or had knowledge about the fundamental concepts of the study and the respondents that had not. For the questions where differences were found, additional frequency distribution bar charts were computed, using the same method as described above.

2.6 Quality assurance

When conducting a quantitative study, validity and reliability are two words/concepts used to describe the trustworthiness of a study. However, since this study is of a flexible rather than a fixed design, which quantitative studies usually are, other central concepts will occur to establish the trustworthiness in this thesis. These concepts are accounted for below.

2.6.1 Validity

Validity means to what extent a concept is accurately measured in a study (Heale & Twycross 2015) or can also be seen as the accuracy of a result from a realist perspective (Robson & McCartan, 2016), thus whether the findings ‘really’ are about what they appear to be about. In this study the validity of the data is high, as the respondents of the sample are seen as a total population. Because of this there is no difference between the sample and the total population. Albeit, there can be a number of factors that can lower the validity in the data set. Examples could be the sampling method or how individuals answered in the survey.

2.6.2 Triangulation and reliability

Robson and McCartan (2016) also describe issues of bias and rigor. Where some of the concerns are not applicable in this study, two of them are triangulation and reliability.

Triangulation can help to counter all of the threats to validity, according to Robson and McCartan (2016, p. 171). In this study, triangulation has been used to try to eliminate bias. In Table 2, four types of triangulation are described according to Denzin & Lincoln (1994). Table 2 also indicates how the type of triangulation is accounted for in this thesis.

Table 2. Overview of different types of triangulation according to Robson & McCartan (2016, p. 171) and how it was accounted for in this study

Type of triangulation:	**How it was accounted for in this study:**
Data triangulation: More than one type of data collection	Except the empiric data in this study other data has also been collected. E.g. from different public platforms such as statistics from Statistics Sweden.
Observer triangulation: Using more than one observer in the study	In this study there were two authors discussed difficult questions, cases and how the data should be interpreted.
Methodological triangulation: Combining quantitative and qualitative approaches	Due to time limitation the study was carried out with quantitative data.
Theory triangulation: Using multiple theories or perspectives	In the theory chapter different theories are used to help analyse the subject, but mainly the theory by Geels (2018) is used.

In Table 2, the different types of triangulation are considered. In this study, all the four different types of triangulation are used, though in different extent and rigour. This can be seen in, e.g. observer triangulation, where the thesis only can hold two authors compared with an article that can host many more observers and writers.

Reliability is how well an instrument produces consistent results (Robson and McCartan, 2016, p. 173). In this study, the main instrument of observation was the survey carried out at IKEA Uppsala. Threats against reliability, according to Robson and McCartan (2016), can be that people do not understand the questions (participant error) and do not answer what they think (participant bias). One way to improve the study's reliability was to be present when the surveys were answered and to be able to answer questions regarding the survey. If the respondents had problems understanding the questions or needed help with technical matters, the authors were there to help. Reliability was also raised with a limited number of computers, as the authors had more time for each respondent with fewer computers that collected the answers. If answering by the paper had been applied instead, the number of respondents that answered the survey at the same time could have been more, and the reliability would be lower.

2.6.3 Generalizability

When talking about generalizability one can talk about internal and external generalizability according to Robson and McCartan (2016). Internal refers to the generalization within the setting studied and external generalizability refers to the generalization beyond the studied setting (*ibid*). In this study the external generalizability is low, since the study is of an exploratory design and the sampling method is convenience sampling. Therefore, no statistical evidence can be presented except of descriptive nature for the sample that was surveyed. However, this case study can play an important role as a guidance for future studies and also serves as a snapshot of the people who visited IKEA during the period of data collection. This snapshot can in the future be used in a similar study to measure the difference between two points in time.

2.6.4 Non-response analysis

During the weekend of the data collection, many people visited the IKEA warehouse in Uppsala. The IKEA-personnel was not able to give the authors the exact number of visitors during the time of the survey due to business confidentiality. Though, they could say

approximately how many percents of the visitors had answered the survey. During the weekend, approximately 1,4 % (n=204) (pers. com Birath, 2018) of the visitors answered the survey.

Some surveys were unfinished and therefore, not included in the study. There were three main reasons why the respondents did not complete the survey; the survey was too long, too hard to understand or took too much of their time. As the survey could be answered in both Swedish and English, most respondents were able to fill it in. However, some did not finish the survey due to a lack of understanding of the two languages. The uncompleted surveys (n=22) is to be compared with the completed surveys (n=204).

2.7 Ethical considerations

Bryman & Bell (2017 p. 141) points out the most important ethical principles to consider when handling data where people are involved. The most important can be seen in Table 3. How these ethical principles were handled in this study is also shown in Table 3.

Table 3. A summary of the most important ethical considerations according to Bryman and Bell (2017 p. 141) and how project related concerns were made part of the quality assurance

Needs for ethical consideration (Bryman & Bell, 2017, p. 141)	**Project related concerns that were made as part of the quality assurance**
Information, the researchers have to inform the respondents about the purpose of the research and which elements that are included.	The respondents in this study were informed before participating in the survey about the purpose of the study and the use of the data collected.
Consent, the respondents have to know that their participation is voluntary and have the right to abort their participation at any time.	The survey was based on voluntary participation and the respondents were not obliged to finalize the questionnaire if they no longer wanted to participate. The respondents also had to give their consent that the researchers could use their data in the PerForm project before they carried out the survey.
Confidentiality and anonymity, the information collected in the study and the information about the respondents should be treated with the highest degree of confidentiality.	The respondents were informed about their anonymity and that the answers would be treated with confidentiality.
Usage of information, the information collected should only be used for the research purpose previously stated.	The respondents were informed about the purpose of the study and their rights as respondents including being anonymous and that the data should be dealt with according to the The General Data Protection Regulation (**GDPR**) regulations.
False promises, the researcher should not delude the respondents about the research or give them false information.	The authors did not give any false promises and no false information to the respondents during the collection of data.

In Table 3, an overview is provided of the most central ethical principles when conducting a study where people/respondents are involved. The principals were considered during the whole process of collecting data, handling data and writing about the data.

3 Theory

The theory chapter provides an overview of the concepts and theories used in the analysis. The chapter starts with definitions of key terms in section 3.1-3.3, followed by a presentation of theories about SA of low carbon innovations. Then a presentation of a theory about ST-transitions, which is used as a conceptual framework for the study, follows. Lastly, a short presentation of practice theory, which is used as a complement to the primary theory is presented.

3.1 Definition of bioeconomy

The term BE and other related topics have during the last years increased in popularity in both policies and the scientific society (Bugge *et al*. 2016; Persson 2016; Kleinschmit *et al*. 2017). However, there are several definitions and ways to describe BE, and there is no real consensus on what the concept of BE encapsulates. Hence, the meaning of the term BE is still in flux (Pülzl *et al*. 2014).

How it should be implemented and achieved is still debated around the world and, therefore, both the interpretation and implementation of the BE concept vary among regions and nations. On the global scale, the Organisation for Economic Co-operation and Development (**OECD**) offers one definition which focuses on biotechnology and innovations in the sectors of agriculture, industry and health (Skånberg *et al*. 2016 p. 3). A similar emphasis on biotechnology is also indicated by the US definition of BE (The White House, 2012). The EU introduced its first definition of BE in 2012. However, the concept has evolved as a new and broader definition was adopted in 2018 (European Commission 2018b). Besides, the Nordic Minister Council also has a definition, which focuses more on the conditions in the Nordic countries (Nordic Bioeconomy Programme 2018). To narrow it down, even more, Sweden has a BE research agenda and a definition set by the Swedish Research Council for the Environment, Agricultural Sciences and Spatial Planning (**FORMAS**) (FORMAS 2012). All these definitions are briefly presented in Appendix III, and the most important definitions for this study are also presented in Table 4, below.

Table 4. Overview of some definitions of bioeconomy

Organisation (Year)	**Definition**
European Commission (2018)	"*The bioeconomy covers all sectors and systems that rely on biological resources (animals, plants, micro-organisms and derived biomass, including organic waste), their functions and principles. It includes and interlinks: land and marine ecosystems and the services they provide; all primary production sectors that use and produce biological resources (agriculture, forestry, fisheries and aquaculture); and all economic and industrial sectors that use biological resources and processes to produce food, feed, bio-based products, energy and services. (To be successful, the European bioeconomy needs to have sustainability and circularity at its heart. This will drive the renewal of our industries, the modernisation of our primary production systems, the protection of the environment and will enhance biodiversity)*" (European Commission, 2018b, p. 27).
Nordic Minister Council (2018)	"*The bioeconomy encompasses the utilisation of renewable biological resources and the conversion of these resources (including side- and waste streams) into value-added products, technology and services. The products include food, feed, bio-based products, chemicals, materials and bioenergy, while services include, for example, water and air quality, shelter and recreation (e.g. walking, skiing and foraging for berries and mushrooms) and non-anthropogenic outcomes like biodiversity"* (*Nordic Bioeconomy Programme*, 2018, p. 10)

The definitions presented in Table 4 are only a selection of definitions. However, the core idea of BE is to replace the non-renewable fossil-fuel used in industrial production and for energy supply by renewable biogenic feedstock (Priefer *et al*. 2017 p. 1).

Sweden does not have its definition of BE, solely definitions which are developed by Swedish organisations or definitions which are developed jointly with other countries. The EU definition of BE from 2018 was used in the PerForm project, primarily because it is a collaboration project at the European level. The survey used in this project was, therefore, developed based on the EU definition from 2018. However, in this study, we choose to apply the definition of the Nordic Minister Council, as it is more adapted to Swedish conditions and also includes ecosystem services such as recreation, water quality and biodiversity.

3.2 Definition of forest-based bioeconomy

Staffas *et al*. (2013) argue that there is a difference between BE and bio-based economy. While BE primarily focuses on parts of an economy that involve biotechnical and life science elements, bio-based economy describes an economy which mainly uses biomass resources, rather than fossil-based ones.

"In short, the "bio-economy" is often understood as a sector, whereas the "bio-based economy" refers to a transformation of the economy as a whole" (Staffas *et al*., 2013, p. 2765).

FBB is a bio-based economy in which forest resources are the primary biomass resource. It is more easily defined than BE, but some problems regarding its definition still exist, foremost about what should be included in the definition (Winkel & European Forest Institute, 2017). As with BE, there are several definitions around the world, mainly from forest organisations and countries with a vast forest resource (Winkel & European Forest Institute, 2017). A European and Canadian example of definitions is presented in Table 5.

Table 5. Overview of definitions of forest-based bioeconomy

Country/organisation	Definition
Winkel *et al*, EFI	***"...a forest-based bioeconomy should encompass economic activities relating to all forest ecosystem services****, ranging from forest biomass to tourism, recreation and non-wood products."* (Winkel & European Forest Institute, 2017, p. 4) (Winkel & European Forest Institute, 2017, 12).
Canada	*"The forest bioeconomy refers to economic activity generated by converting sustainably managed renewable forest-based resources, primarily woody biomass and non-timber forest products, into value-added products and services using novel and repurposed processes"* (Canadian Council of Forest Ministers & Innovation Committee, 2017, p. 4)

As indicated by Table 5, the definitions are similar, but the emphasis on sustainably managed forests and different ecosystem services differ. In this study, a definition in line with the definition by Staffas *et al*. (2013) is used. FBB is here defined as an economy which mainly uses forest biomass resources, where appropriate. FBB is therefore seen as a transition to the use of renewable and sustainably managed forest resources in the whole economy or a part of it. Similar to Winkel & EFI (2017), FBB encompasses economic activities relating to all forest ecosystem services, which means that forest biomass in the form of wood products as well as services such as tourism can be included.

As an LCT can take place within a part of the economy, the housing system and primarily the multi-story buildings sector was chosen as an example of a part of the Swedish economy where FBB can be implemented. In the next section, the innovation of WMBs, which have the potential to enable a transition towards FBB within the multi-story buildings sector, is presented.

3.3 Definition of wooden multi-story buildings

Traditionally multi-story buildings in Sweden are built with a steel and concrete frame (Hemström *et al*. 2012). However, the climate impact of these buildings can be minimized through a change in material use from steel and concrete to wooden frames (Perez-Garcia *et al*. 2005; Dodoo *et al*. 2012; Gong *et al*. 2012; Nässén *et al*. 2012). Previous studies on multi-story buildings with wooden frames have used different terminologies to describe these buildings. Mahapatra & Gustavsson (2008) refer to these buildings as multi-story timber buildings. Hemström *et al*. (2012) use the term multi-story wood-frame buildings, while Hurmekoski *et al*. (2015) instead focus on wood-frame multi-story construction. In contrast, Riala & Ilola (2014) use multi-story building construction, and Skullestad *et al*. (2016) introduce the terminology of high-rise timber buildings. There is no consensus on how to define these buildings.

The definition used in this study is multi-story buildings with a mostly wooden frame, which is referred to as wooden multi-story buildings (**WMBs**). This definition was chosen because it was used in the survey questions designed by the PerForm-team. In this study, a WMB is a building with more than two storeys, primarily because Statistics Sweden choose to define multi-story buildings in this way and statistics from Statistics Sweden are used in this study. Lastly, the term building and construction is used complementary in this study, referring to WMB, primarily because both terms are used simultaneously in literature.

As the SA of WMBs and FBB is of primary interest in this study and can be seen as examples of low carbon innovations, a framework for SA of low carbon innovations is presented in the next section.

3.4 Social acceptance of low carbon innovations

As argued in the introduction, there are several reasons why SA is important when low carbon innovations are established on the market; public acceptance is needed to implement low carbon policies, and customer acceptance is needed for low carbon innovations to take place on the market. In the renewable energy sector, this has become increasingly recognized, as, wind park projects have caused public debate (Wüstenhagen *et al*. 2007). To be able to study the SA of renewable energy innovations, Wüstenhagen *et al*. (2007) put forward a model which is presented in the next section.

3.4.1 Social acceptance of renewable energy innovation model

In the renewable energy sector, ambitious political targets have been set by several governments since the 1980s to increase the amount of renewable energy supply offered on the market. Some of these policies have been more successful than others. Despite some success, several scholars identified that SA of renewable energy innovations is a constraining factor for the market implementation of these innovations (Wüstenhagen *et al*. 2007).

Wüstenhagen *et al*. (2007) introduced a model aiming at clarifying the concept of SA as it is not clearly defined in the literature, even though it is commonly used. Figure 1 illustrates the model by Wüstenhagen *et al*., (2007), which constitutes of three dimensions of SA.

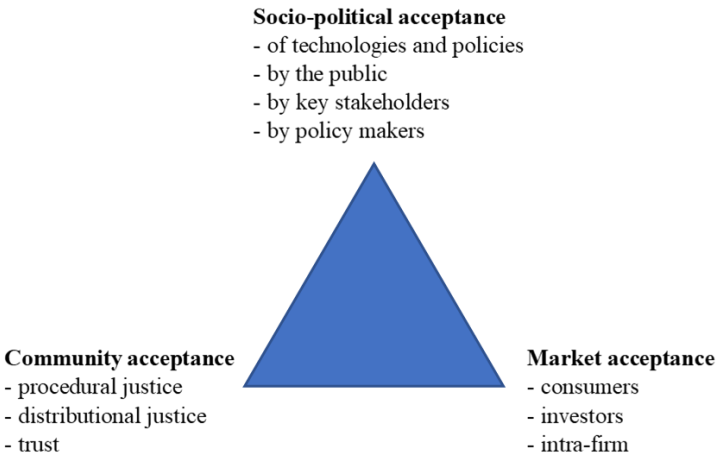

Figure 1. The triangle of social acceptance of renewable energy innovation with minor modifications (Wüstenhagen et al., 2007, p. 2684).

As indicated by Figure 1, the three dimensions of SA are socio-political acceptance, community acceptance and market acceptance, which are described in more detail below.

Socio-political acceptance

This dimension of SA concerns the acceptance of technologies and policies and is the most general level of the SA triangle. The socio-political acceptance level is made up of three groups; the public, key stakeholders and policymakers and concern, for example, the general acceptance in society of wind parks (Wüstenhagen *et al*., 2007).

Community acceptance

The second dimension of the SA model is community acceptance, which is a more local level of acceptance. It involves local stakeholders who are affected by renewable energy innovations in specific places. Local stakeholders can, for example, be residents or local authorities. It is on this level that the question about "not-in-my-backyard" is brought up, where local stakeholders can be positive towards innovation on the general socio-political level (e.g. wind parks), but do not like it to be established close to their home (e.g. a wind turbine next to their home). The community acceptance level is influenced by three factors; distributional justice, procedural justice and trust. Distributional justice refers to the fair distribution of costs and benefits connected to the establishment of the innovation. Procedural justice asks if the decision-making process has involved all stakeholders and trust means that local stakeholders feel that they can trust the objectives and the information from investors and other actors (Wüstenhagen *et al*. 2007 p. 2685).

Market acceptance

The last dimension is market acceptance, which primarily concerns the market adoption of renewable energy innovation. Market acceptance focuses not only on end consumers but also on investor and intra-firm acceptance. This dimension applies thoughts from the diffusion of innovation literature where the adoption of an innovation is seen as a communication process between the adopter and its environment (Wüstenhagen *et al*. 2007).

3.4.2 Social acceptance of green building framework

The framework of SA of green buildings was developed by Zhao *et al*. (2015) and built upon the model of Wüstenhagen *et al*., (2007) and the concept of green building. The concept of green buildings combines ecology and architecture to create sustainable places for humans to live. The aim is to offer users comfortable and healthy spaces through efficient use of resources so that the impact on the environment is minimised. The impact is considered through all stages of the lifecycle of the building, including the material production to demolition and recycling of the building (Zhao *et al*., 2015). According to Zhao *et al*. (2015), green buildings can be seen as a reform in the building industry as:

"Goals in marketing residential and commercial spaces have changed from achieving occupancy rates to systematical controlling the construction to provide a healthy, and comfortable space for activities, as well as sustainability for space" (Zhao et al. 2015, p. 1595).

The change in marketing goal put forward by Zhao *et al*. (2015) lies much in line with the shift from product-dominant logic to service-dominant logic suggested by Vargo and Lusch (2004). Product dominant logic puts focus on tangible resources and transactions, while service-dominant logic focuses more on intangible resources, co-creation and relationships (Vargo & Lusch 2004 p. 1).

The SA of green buildings framework is, as explained above, built upon the concept of green buildings and the model developed by Wüstenhagen *et al*., (2007). Zhao *et al*. (2015) develop the model further by illustrating the principal elements of the different dimensions of SA. Zhao *et al*. (2015) also suggests what roles different stakeholders should have in the establishment of green buildings.

In this study, SA is measured through perceptions of the respondents of the survey used in this study. The SA framework is used to explain and illustrate which dimensions of SA are analysed in this study. Therefore, the framework is not used to identify principal elements of the different dimensions or to suggest what roles different stakeholders have. The SA framework is used complementary to the MLP on ST-transitions, mainly because the unit of analysis in this study are the conditions for change and how public perceptions affect it, rather than public perceptions in itself. The main theoretical framework of ST-transition theory is explained in more detail in the next section.

3.5 Socio-technical transition theory

The main theory of this study is the socio-technical transition theory. In this section, different concepts of it are presented. Firstly, the perspective of the socio-technical transition theory is defined. Secondly, the concept of socio-technical systems is presented, and lastly, an explanation of the multi-level perspective of the socio-technical transition theory follows.

3.5.1 Perspective of the socio-technical transition theory

The ST-transition theory is built upon the perspective that technology in itself has no function. It has a function in social settings only:

"Only in association with human agency, social structures and organisations do technology fulfil a function" (Geels 2002 p. 1257).

Therefore, transitions are not only technical but also social, as technology serves no purpose if it is not put in a social setting. Therefore all the concepts presented below have both a social and a technical dimension.

3.5.2 Socio-technical systems

The concept of socio-technical systems (**ST-systems**) was developed by Geels (2004). It is built upon the thought that technology is not only tangible items such as wind power stations but also systems of intangible elements such as skills, routines, behaviours, infrastructures and organisations needed to operate the tangible item (Rip & Kemp 1998). According to Rip & Kemp (1998, p. 327) technology is "configurations that work", which Geels (2002, p. 1257-1258) interpreted as an arrangement of elements or parts that fulfil a function. Furthermore, a technological configuration also includes the societal context in which the technology is developed and used (Rip & Kemp, 1998).

The early work by Geels (2002) used the Rip & Kemp (1998) concept of technological configurations. Geels (2002) further developed it, claiming that the configurations that fulfil societal functions are called socio-technical configurations (**ST-configurations**). Geels (2004) later renamed the concept of ST-configurations to ST-systems. An ST-system is defined in the same way as an ST-configuration (Geels, 2002, 2004). The concept of ST-systems is used in this study, as it is the concept currently used by Geels, and he is a popular author in this field (Geels *et al*. 2017; Geels 2018). Below an example of an ST-system is presented, showing the elements of a system fulfilling the function of road transportation (Figure 2).

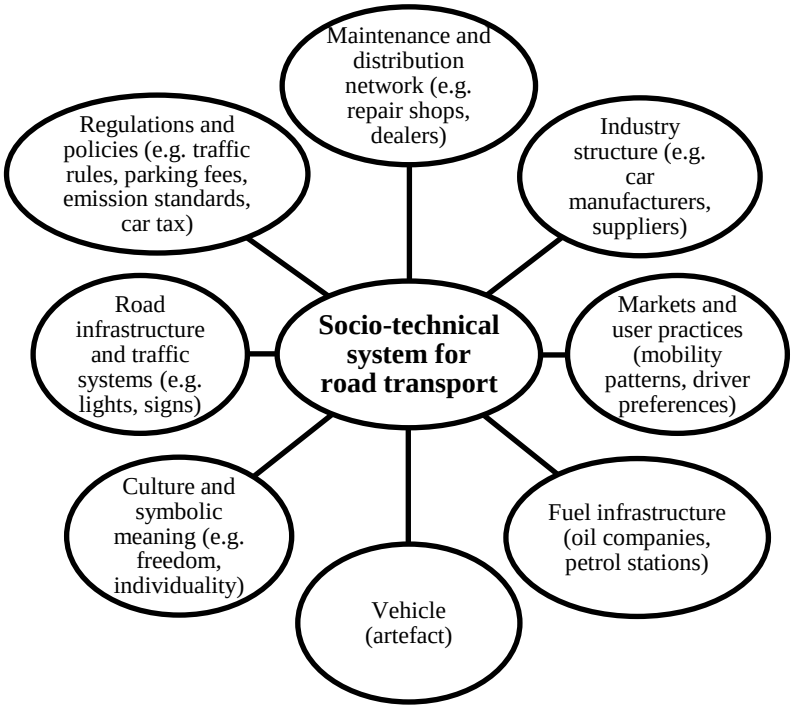

Figure 2. Tangible and intangible elements of the socio-technical system of road transportation with minor modifications (Geels et al., 2017, p. 465).

The ST-system of road transportation seen in Figure 2 includes not only tangible items such as the vehicle but also intangible elements such as fuel infrastructure, regulations and policies, markets and user practices, among else (Geels, 2004). It is through the arrangement of these elements that the function of road transportation is fulfilled in society. Examples of other social

functions that are fulfilled through different ST-systems are sustenance, communication, mobility, heat and housing (Geels *et al*., 2017).

According to Geels (2002), ST-systems are resistant to change. This resistance is explained by several reasons, some of which are:

1. *The interdependence of elements.*
   The elements of an ST-system are interdependent, which means that the mix of technologies, supply chains, infrastructures, markets, regulations, user practices and cultural meanings are closely connected and have tight linkages to each other making change difficult (Geels *et al*., 2017).

2. *Co-evolution of elements.*
   The elements of an ST-system also co-evolve during long periods, sometimes decades, creating strong linkages to each other (Geels, 2004).

3. *Hardness in artefacts and material networks.*
   Tangible element of ST-systems such as artefacts and material networks, inhibit a certain hardness and can also be challenging to change mainly because a material structure such as an industrial facility or a power plant might not be quickly abandoned due to substantial investment costs, etcetera. (Geels, 2004).

4. *Material artefacts embedded in society.*
   Another reason why ST-systems are resistant to change is that material artefacts become embedded in society, making people adapt their lifestyle to that particular artefact. Because of the high rate of adoption in society, a change in technology becomes unthinkable (Geels, 2004). One example of such an artefact could be the car.

5. *Economic considerations.*
   Lastly, there are economic reasons why an ST-system is upheld. Sunk investments might have been done in the current technology and ST-system, making it unfavourable to invest in new technology. Companies also tend to stick to established technologies because of advantages created through economies of scale and because of knowledge about the current technology (Geels, 2004).

However, these systems are not unchangeable, and when a change in an ST-system occurs, it is called an ST-transition (Geels, 2002; Geels *et al*., 2017). An ST-transition includes changes in the tangible technology, such as the car in the road transportation example given above, but also changes in the intangible elements, such as user practices or regulations. The existing infrastructure, legalization, user practices and industry structures are arranged to make the current technology function and therefore radically new technologies struggle to break through as they often require changes in the current ST-system to function (Geels, 2002).

3.5.3 Multi-level perspective

The overall dynamic patterns of ST-transitions can be described through the analytical framework called the multi-level perspective (MLP). The MLP combines concepts from several areas, for example, evolutionary economics as well as science and technology studies (Geels, 2011). The MLP consists of three analytical and heuristic levels, which are closely linked to each other. These levels shall not be seen as ontological descriptions of reality (Geels, 2002).

The MLP describes ST-transitions as nonlinear processes which emerge as a result of developments in the three analytical levels. The three levels are niches (where radical innovation takes place), ST-regime (upholds the stability of the existing ST-system as this is where established practices and rules are located) and the ST-landscape (the context which influences the other two levels) (Geels, 2011). Figure 3 shows an illustration of the MLP.

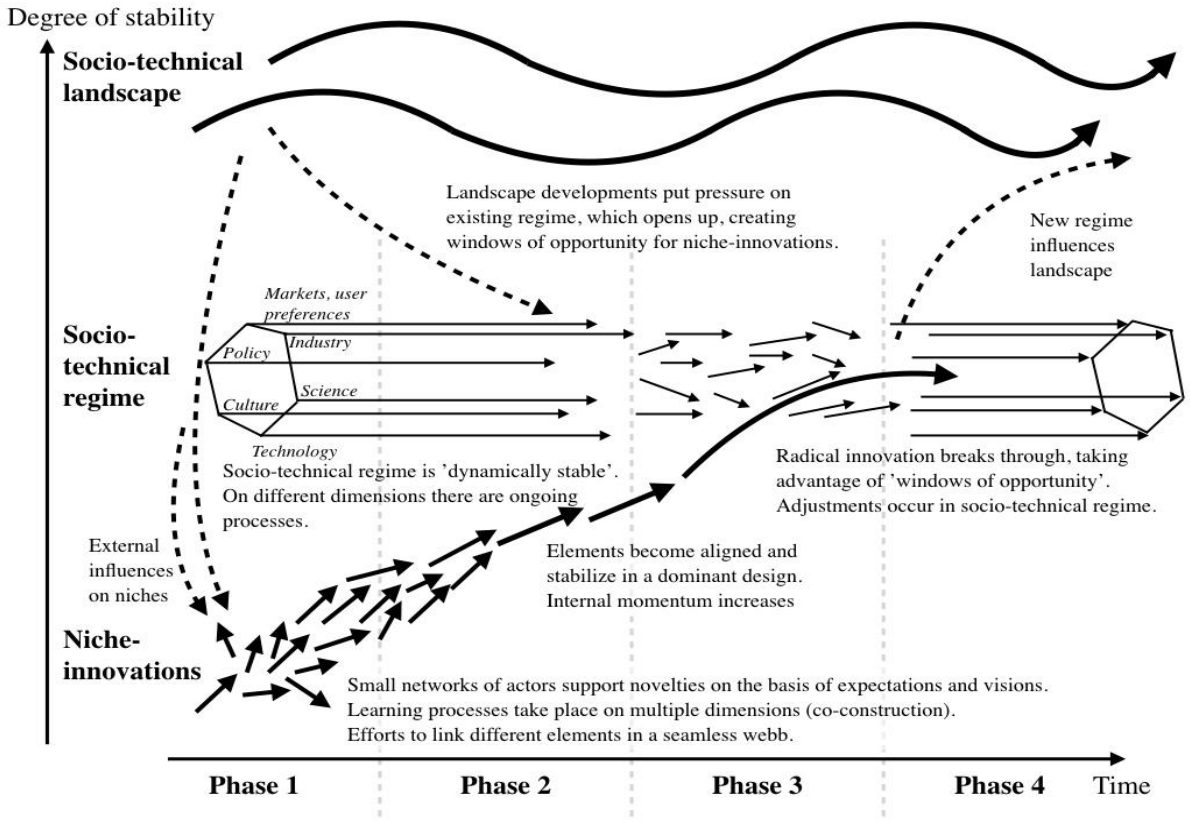

Figure 3. Illustration of the multi-level perspective theory on socio-technical transitions with minor modifications (Geels, 2018, p. 226).

The y-axis of Figure 3 represents the degree of stability in the different levels. The arrow pointing upwards indicates that the degree of stability increases with each level. The reason is that each level has its configuration of elements and number of actors. On the higher levels of the MLP, more actors are more strongly linked to each other, resulting in more stability and less opportunity for radical change (Geels 2011). The levels of the MLP will be explained in more detail below.

Socio-technical regime

Geels (2011) defines ST-transitions as *"...shifts from one regime to another regime*" (Geels, 2011, p. 26). This middle level of the MLP is therefore of primary interest when studying transitions and will be explained ahead of the other two levels, both in this chapter and in the coming. The ST-regime can be explained as the predominant paradigm (Geels, 2004), determining practices and ways of thinking (Geels, 2002). It can also be defined as:

"The socio-technical regime forms the 'deep structure' that accounts for the stability of an existing socio-technical system. It refers to the semi-coherent set of rules that orient and coordinate the activities of the social groups that reproduce the various elements of socio-technical systems" (Geels, 2011, p. 27).

The rules mentioned above interact with actors of the ST-regime in two ways. Firstly, the rules are determined and set up by the actors. Secondly, they also regulate the actions carried out by the actors. Geels (2011) gives some examples to clarify the rules of the ST-regime:

"Examples of regime rules are cognitive routines and shared beliefs, capabilities and competencies, lifestyles and user practices, favourable institutional arrangements and regulations, and legally binding contracts" (Geels, 2011, p. 27).

The ST-regimes are not easily changed due to the nature of these rules, and therefore, only incremental innovation takes place in this level of the MLP-model (Geels, 2011). Incremental innovation improves existing products, systems, technology or markets and does not result in shifts in the ST-regime like radical innovation (Garcia & Calantone 2002). Because small adjustments to current solutions are made, the changes follow stable paths, courses or directions, which are called trajectories (Geels, 2011).

Trajectories exist not only for the technological element of the ST-regime but also for markets and user preferences, industry, science, policy and culture. In Figure 3, these trajectories are shown as the straight arrows connected to each of the previously mentioned elements of the ST-regime level. All these elements are made up of their dynamic and can be seen as sub-regimes. However, these sub-regimes are linked together and co-evolve (Geels, 2011), which is shown through the polygon attached to the sub-regime arrows in Figure 3.

The ST-regime aims to illustrate the linkage between the different sub-regimes and the stability it provides to the whole ST-system. Pressure on the ST-regime from both the niche and the ST-landscape can, however, lead to tensions that break up the regime (illustrated as numerous arrows in the central part of the ST-regime in Figure 3), creating windows of opportunity for radical innovations (Geels, 2011).

As mentioned earlier, the ST-regime is in the centre of the MLP. Therefore are the niches and the socio-technical landscape (ST-landscape) defined in relation to the regime (Geels, 2011). How they are defined will be explained in more detail below.

Niches

While incremental innovation takes place within the ST-regime, radical innovation takes place in the niches (Geel, 2011). Innovation is said to be radical when it results in outcomes that create new market infrastructures. The outcomes can be, for instance, technologies, systems or services. Because radical innovations are new, they cause discontinuities in several areas, such as the market, industry or society, but also in companies and for customers. Radical innovation does not originate from a widely held customer need. Instead, it aims at creating something profoundly new, which is why radical innovation creates opportunities for new industries to emerge (Garcia & Calantone, 2002). One example of radical innovation is the computer, which has changed the world profoundly and created a market for numerous new companies since it was developed.

Niches are protected spaces in the MLP-model where radical innovation takes place. As radical innovations differ substantially from the existing regime and do not fulfil needs that exist in the market today, they need to be developed in protected spaces. Examples of such protected spaces can be demonstration projects which are subsidised, small markets that get targeted policy support, research and development (R&D) laboratories or a fraction of a market which is willing to pay extra for potential innovations (Geels, 2011).

Niche-actors are the people and organisations that carry out radical innovation. Their wish is for their innovation to take place in the ST-regime or even replace it (Geels, 2011). As mentioned in section 3.1.2, this is not quickly done as the elements in the regime are designed for the current technology rather than the new technology (Geels, 2004). Examples of this can be that regulations are not adapted for new technology, that infrastructure is built for the dominant technology or that users have little knowledge on how to use it.

The niche innovation level of the MLP is illustrated in Figure 3 by the multiple small arrows pointing in different directions in the lower-left corner of the figure. As the elements of the niche innovation become more aligned, networks of actors expand, and a dominant design of the new technology is established, the internal momentum in the niche increases, creating an opportunity for the innovation to advance and take place in the ST-regime (Geels, 2018). In Figure 3, this process is illustrated by the longer and more aligned arrows.

Socio-technical landscape

The ST-landscape overlooks and influences interactions between the ST-regime and the niches of the MLP. It can be seen as the in-depth structural trends (Geels, 2002) or the broader context, which combine elements such as macroeconomic patterns, political ideologies, demographic trends, the environment and societal values (Geels, 2011). It also involves material and spatial arrangements in the society which are not easily changed, such as where and how factories, cities, transportation networks or energy systems are built. Moreover, cultural and religious values, natural disasters, conflicts and other external elements that affect the ST-regime and the niche are included in the ST-landscape (Geels, 2002).

Because of the solid linkage between the elements of the ST-landscape, changes occur only very slowly. What distinguishes the ST-landscape from the other levels is that the landscape cannot be influenced by actors of the MLP in the short-run (Geels, 2011). However, the developments that take place in the ST-landscape have the power to put pressure on the ST-regime and by that create opportunities for new technologies to emerge (Geels, 2018). The dynamics of the ST-landscape are illustrated in Figure 3 as the top wavelike arrows (representing the stability of this level) and the crosshatch arrows (representing the changes in different levels of the MLP).

Dynamics of the multi-level perspective

This section describes the dynamics and processes of the MLP to clarify how ST-transitions take place. An ST-transition is the result of interactions between processes on the different levels of the MLP. According to Geels (2011), there is a general pattern that exists in most transitions:

"... (a) niche-innovations build up internal momentum, (b) changes at the landscape level create pressure on the regime, and (c) destabilisation of the regime creates windows of opportunity for niche-innovations" (Geels, 2011, p. 29).

The MLP stresses that there is no single actor, cause or driver that initiates transitions, but rather interconnected processes in multiple dimensions that reinforce each other and create transitions (Geels, 2011).

Transitions are divided into four phases, as shown in Figure 3. In the first phase of radical innovation takes place in niches. Here networks are unstable, and many innovative solutions are created, of which many fail. In Phase 2, networks of actors start to stabilise, and a dominant

design is created, which enters small niches in the market. In the third phase, the innovation gains more ground and starts to compete with the dominant technology in the ST-regime. In the fourth and last phase, the technology in the ST-regime is substituted, making the innovation the dominant one. This leads to the elements in the ST-regime being adapted to the new technology (Geels *et al*. 2017).

3.5.4 Critique of the multi-level perspective

The MLP framework on ST-transition has received some criticism. Table 6 gives an overview of the different areas where the MLP has been criticised. A more detailed overview is presented in Appendix IV.

Table 6. Overview of critique against the multi-level perspective of socio-technical transitions, how it has been responded to and handled in this study

Criticism	**Response**	**How the critique is handled in this study**
Use of secondary data Many studies that have applied the MLP have been case studies that have made use of secondary data sources. This has been criticized by Genus and Coles (2008) who argue: *"Indeed certain case studies do not set out adequately the research methods governing the collection and analysis of (secondary) data, and rely uncritically on a small number of quite recent accounts of the topic in question, themselves based on secondary data, rather than on documents contemporaneous with the historical period being studied…. If the case studies are constructed poorly or related sources used uncritically then the strength of the MLP as a whole is undermined"* (Genus & Coles, 2008, p. 1441).	This critique is recognized by Geels (2011), who admits that transition case studies have been more illustrative and exploratory than systematic. However, there are also examples of early MLP-studies that have used primary data sources (Geels, 2011). More recent studies have also used primary data (Matschoss & Heiskanen 2018; Reichenbach & Puhe 2018).	This study focuses on a transition that is happening right now. Therefore, primary data is much easier to get hold of than if a historical transition were to be studied. This study is based not only on secondary data but also on primary data from a questionnaire, which is why this critique has been accounted for.
Influence of the analyst Genus and Coles (2008) are also critical of the high influence that the analysts choices have on MLP-studies. As an example, the analyst chooses and interprets: which cases to research, what information should be used and at what level of the MLP, start and end point of the transition, path articulation, among else (Genus & Coles, 2008, p. 1442-1443).	This critique has not yet been responded to.	Genus and Coles (2008) are critical of the influence of the analyst when applying the MLP. Primarily because the choices of the analyst create bias. This critique is legitimate for this study. However, Robson and McCartan (2016) state that: *"Issues of bias and rigour are present in all research involving people"* (Robson & McCartan, 2016, p.171). One way to handle the risk of bias is through triangulation of data, observers, methods or theories (Robson & McCartan, 2016). In

		this study, triangulation of data and methods are applied. The data used is primary data from a questionnaire along with data from other studies and information available from governments and other organisations.
Poor conceptualization of processes of final consumption According to McMeeking & Southerton (2012) the MLP put too much focus on special users who are early adopters of new technologies and fail to recognize the mass of ordinary consumers (McMeeking & Southerton, 2012, p. 347). As they see it; *"ordinary users are viewed as a relatively homogeneous group trapped within the incumbent socio-technical regime; their attachments to existing technologies provide stability to that regime and are a source of resistance to radical innovations. Changes in mass consumption, within this class of ordinary users occur in a reactive fashion only after disruption at the landscape level and when the innovative niche level work of avant garde producers and 'special users' has gained some momentum."* (McMeekin & Southerton 2012 p. 348).	McMeeking & Southerton (2012) argue that the main focus of the MLP has been on the producers, their innovations and on political governance that have the possibility to influence transitions, not on transitions in consumptions. Therefore, they suggest that a practice based approach could be combined with the MLP to add more focus on final consumption. Practice theory can be used to study what people do as well as why and how their practices influence their consumption (McMeeking & Southerton, 2012).	As this study aims to identify enabling and hindering factors connected to final consumption, this critique is justifiable. Therefore, practice theory as a means to explain end consumption is explained in more detail in the end of this chapter and incorporated into the analysis.

In conclusion, the MLP has been criticised for several reasons, as indicated in Table 6. Some of the critiques have been responded to, while some of the critiques have not. For this study, the most important criticism is the inadequate conceptualisation of processes of final consumption of the MLP. To respond to this critique, thoughts and ideas from practice theory are applied in combination with the MLP to put more focus on the significance of consumption in ST-transitions. Practice theory is explained further in the next section.

3.6 Practice theory

Practice theory is not just one single theory, but several theories that are all built on the thought that the world and occurrences in it can be described as:

"...something that is routinely made and re-made in practice using tools, discourse, and our bodies. From this perspective, the social world appears as a vast array, or assemblage of performances made durable by being inscribed in human bodies and minds, objects and texts, and knotted together in such a way that the results of one performance become the resource for another" (Nicolini 2012 p. 2).).

The main focus in practice theory is, therefore, what is done and how that affects the world. Practice theory is processual and sees the world as ongoing performances that are interconnected with each other. In practice theory, the individual is seen as a carrier of practices (Nicolini, 2012) or the intersection of multiple practices in practice theory (McMeeking & Southerton, 2012). However, the individual is only one observation and to understand practices, and multiple individuals have to be analysed (McMeeking & Southerton, 2012).

Practices are also carried out with the help of material things or the body, putting the focus not only on what is done but also with what tools or instruments (Nicolini, 2012). Moreover, different social groups engage in and understand practices differently, which leads to tools and instruments being used differently among social groups (McMeeking & Southerton, 2012). Also, practice theory regards cognition as originating from the practices carried out (Nicolini, 2012). Practice theory can be applied in several fields. However, in this study, the main focus is on practices and consumption.

3.6.1 Practice theory and consumption

Practice theory does not regard consumption in itself as a practice. Instead, consumption is seen as a result of practices that are performed, as products and services are acquired to perform the practices (Warde 2005). According to Warde (2005, p. 137) "activity generates wants, rather than vice versa", which moves the analytical focus from the products and services to the practices in which these are used. In short, practice-based approaches see consumption as a result of unfolding and often path-dependent practices (McMeeking & Southerton, 2012, 352). However, Spaargaren (2003) suggests that consumption and production are linked together, as consumers can only use what producers offer in their practices.

Practice theory is in this study used complimentary to the MLP on ST-transition, mainly to help identify enabling and hindering factors for implementing FBB in the multi-story buildings sector in Sweden. Why the MLP on ST-transitions was chosen is described further in the next section.

3.7 Choice of theory

Despite the critique of the ST-transition theory, it is used in this study to assess the feasibility of LCTs because of its abilities to describe transitions. LCTs are substantial changes in the systems that serve society so that these systems become less harmful to the climate. One example of an LCT is the implementation of FBB in Sweden, which aims at reducing the dependence on non-renewable and fossil-based resources by using forest-based renewable resources instead. As the implementation of FBB can be seen as an LCT and the ST-transition theory has been applied in several studies of LCTs (Smith 2007; Verbong & Geels 2007, 2010; Gibbs & O'Neill 2014; Matschoss & Heiskanen 2018; Reichenbach & Puhe 2018) the MLP of the ST-transition theory was chosen as a theoretical framework in this study.

The ST-transition theory provides information about how actors influence the implementation of low-carbon transitions and whether the influence is hindering or stimulating is understood through the MLP. The MLP is typically used to analyse developments in the recent past to help identify drivers and barriers of low-carbon innovations and transition pathways in the present (Geels *et al*. 2016b p. 580). In the following chapters, WMBs represent the niche level of the MLP, while the ST-regime is represented by the dominant steel and concrete constructions in the multi-story buildings sector in Sweden. The ST-landscape level is in this case study the

context around multi-story constructions in Sweden, ranging from climate change mitigation to population increase and the need for new housing.

As mentioned above, the ST-transition theory gives information about the SA of LCTs and how different actors influence the implementation of these transitions. The SA model of low carbon innovation developed by Wüstenhagen *et al*. (2007) and Zhao *et al*. (2015) suggests that there are three dimensions of SA. In this thesis, the SA model is used to sort the respondent's perceptions of FBB and WMBs. This study focuses on two of the three dimensions suggested by Wüstenhagen *et al*. (2007), which is indicated in Figure 5.

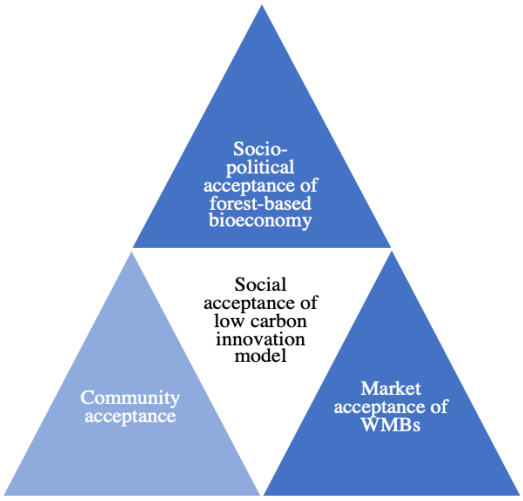

Figure 4. The social acceptance of low carbon innovation model and how it is applied for forest-based bioeconomy, adapted after Wüstenhagen et al. (2007, p. 2684).

The dark blue triangles in Figure 5 show the dimensions that are the main focus in this study, namely; the socio-political acceptance of FBB and the market acceptance of WMBs. The light blue triangle concerns community acceptance, which is not regarded in this study.

As both the socio-political acceptance and the market acceptance is examined in this study, the respondents are seen as both citizens and consumers. Citizens make up the socio-political acceptance dimension of the model, which mainly focus on citizens' perceptions of FBB, while customers or users of low carbon innovations make up the market acceptance dimension of the model. This part of the model focuses on how customers perceive the niche innovation of WMB in comparison to the dominant ST-regime.

In short, the SA-model is used to sort different types of social acceptance in the empirics and analysis. The MLP is used to explain the multi-story housing system in the background empirics, the empirics and the analysis. Practice theory is then applied in the analysis to explain processes of final consumption.

In the coming chapters the empirical findings about how the public perceive the LCT of FBB and the low carbon innovation of WMBs is presented and analysed. However, first a background to the multi-story buildings sector in Sweden follows.

4 Background for the empirical study

The multi-level perspective on socio-technical transitions is used as a theoretical framework in this study. Therefore, this section presents background empirics based on the MLP to provide an understanding of the dynamics behind the transition towards implementing FBB in the system of housing in Sweden. In this section, the ST-regime is represented by the dominant steel and concrete constructions. WMBs represent the niche level of the MLP, while the ST-landscape level is the context around multi-story constructions in Sweden. The reason why the ST-regime is accounted for first is that the two other categories are defined based on the ST-regime.

4.1 Socio-technical regime

This section presents the ST-regime as it is described by Geels (2002; 2004; 2011) of multi-story buildings in Sweden. The ST-regime is made up of several sub-regimes which include culture, policy, industry, technology as well as markets and user preferences. These sub-regimes is considered below.

4.1.1 Culture

Sweden has a tradition of building in wood due to its vast forest resources (Mahapatra & Gustavsson 2008). The oldest wooden buildings that still exists was built in the 13th century (Harrison 2011). The tradition of building in wood is strong even today, as around 90% of the newly built single-family houses in Sweden are built in wood (Hemström *et al*., 2012). However, this does not apply for multi-story buildings, as there was a shift in the late 19th century from wood as the dominant frame material to concrete (Mahapatra & Gustavsson, 2008). The reason for this shift is explained by changes in technical understandings of construction properties that led to policy changes.

4.1.2 Policy

In order to understand the current policy stands for WMB, a historical background may offer some insight. In the late nineteenth century, several countries in Europe experienced large city fires, which eventually resulted in the introduction of fire protection measures (Hemström *et al*., 2012). These fires also happened in Sweden, where cities like Sundsvall and Umeå were hit by city fires (Rosenholm 2013). As a consequence, a law was imposed in 1874, prohibiting the use of wood frames in multi-story buildings (Hemström *et al*., 2012). As a result of the fire protection measures, the concrete industry dominated the multi-story buildings sector in Sweden in the next century (Bengtson 2003; Mahapatra & Gustavsson 2008).

Concrete was first introduced in Sweden in 1863, and the first cement factory was built in 1872/1873 (Bengtson 2003). In the beginning, most of the construction was made through handicraft but eventually became more and more prefabricated. In the 1930s and 40's the Swedish government created incentives to industrialise construction, as there was a need to produce affordable housing for low-income households. These incentives resulted in the formation of large contractor companies who, supported by the Swedish government, could invest in capital intensive machinery and thus became more industrialised. When the Swedish parliament decided that 1 million new apartments should be built in ten years in 1965, industrialisation and mechanisation of the construction industry were even further developed (Mahapatra & Gustavsson, 2008).

In the 1980s, construction costs increased, and the Swedish government decided to deregulate the building sector (Mahapatra & Gustavsson, 2008). A similar development was seen in Europe, where the concrete industry also dominated the multi-story building sector up until the 1980s. At this point, a directive from the European Commission (Council Directive 89/106/EEC) opened up for any material fulfilling the functional requirements of the national legislation to be used in building constructions. At the time, Sweden was not part of the EU and was, hence, not affected by the directive (Hemström *et al*., 2012). However, the legalisation had to be changed before Sweden entered the EU in 1995 (Rosenholm, 2013) and therefore, a new building code was introduced in 1994 (Hemström *et al*., 2012). According to the building code adopted in 1994, all buildings had to fulfil the same function, regardless of construction material. The building code has been updated since 1994. However, the focus on function rather than construction material remains the same today (National Board of Housing, Building and Planning 2018a).

The construction industry is not only affected by legislation concerning construction materials but increasingly also affected by climate change mitigation policies. Moberg *et al*. (2018) studied climate change mitigation policies connected to the housing in Sweden. The policy measures concerning housing were divided into subgroups, namely - building design, energy supply, energy use and household appliances. Two types of policy measures were identified, market-based policy strategy, placing the responsibility for climate change mitigation with the individual citizen and command-and-control policy strategy, placing the responsibility with the government. Moberg *et al*. (2018) found that for all subgroups the governing strategy for climate change mitigation connected to the housing in Sweden places the responsibility for mitigation actions with the individual citizen rather than other actors (Moberg *et al*. 2019 p. 505).

4.1.3 Industry

In Sweden, approximately 90% of new residential buildings over two storeys are built with a concrete reinforced frame (Statistics Sweden 2019b). According to scholars, this depends on different factors in the housebuilding industry. The century-long shaping of regulations explains the path dependency of choosing concrete frames when building multi-story buildings in Sweden, education system experiences and cognitive frames of the construction industry professionals (Bengtson 2003; Mahapatra & Gustavsson 2008; Hemström *et al*. 2012).

One of the essential reasons why concrete is chosen instead of wooden frames is the nearly 100 yearlong ban of building more than two storeys in wood. Roos *et al*. (2010) conclude that architects and structural engineers are influenced by normative beliefs about wood and are reluctant to use wood in their designs because of instability, fire, decay and sound transmission. These beliefs mean that the architects and structural engineers instead use concrete solutions than solutions in wood. Furthermore, Roos *et al*. (2010) also conclude that inexperienced engineers were uncomfortable with wooden frames and that architects thought that they had no or little influence on the choice of material when building. Roos *et al*. (2010) also performed a stakeholder analysis and came up with the following power and attitude diagram in Figure 6.

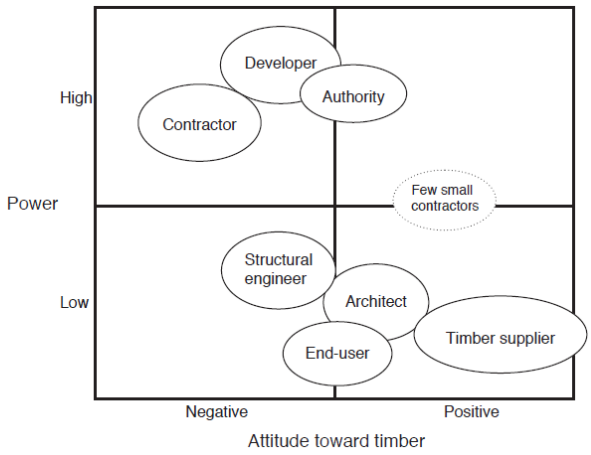

Figure 5. Power of attitude in the process of material selection from Roos et al. (2010) pp 880 with consent from Roos.

Figure 6 illustrates different stakeholder groups' positions with regards to their attitude towards using timber in construction and the power they may exert over decision-makers in sourcing and planning construction. These positions could explain the different standpoints and why it is hard to implement wood frames in the building sector. Other studies also confirm the negative attitude towards wooden multi-story buildings as the preferred frame amongst architects. Hemström *et al*. (2011) confirm the picture of Roos *et al*. (2010) adding that the architects want to build more in wood because of the materials climate effects but that they have little influence on the choice of material in the building process. Moreover, Bengtson (2003) suggests that the concrete industry and other stakeholders have adapted to each other and made their organizations decentralized and, therefore, intertwined to each other's businesses which make the choice of concrete frames easier.

4.1.4 Technology

The dominating ST-regime when building multi-story buildings in Sweden is to use a frame out of concrete, which can be seen in the data provided by Statistics Sweden (2018) interpreted by the authors in Figure 7 below.

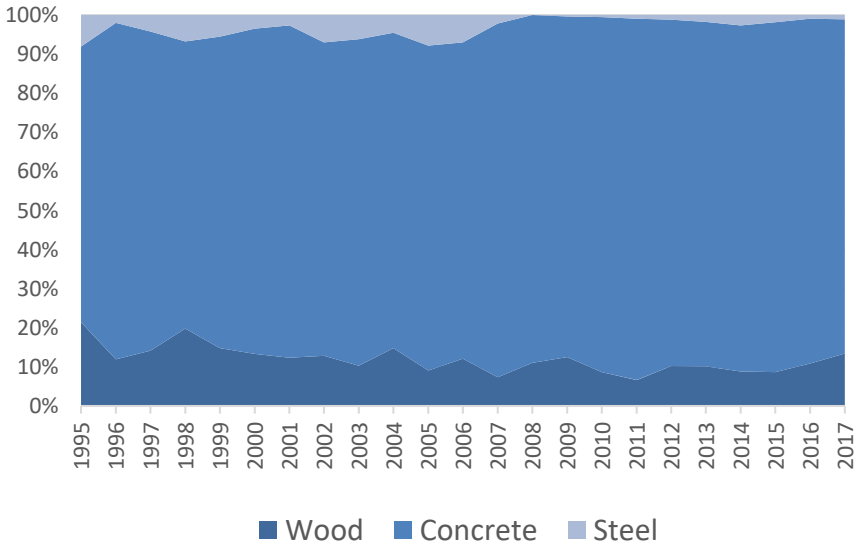

Figure 6. Percentage of frame material used for buildings in Sweden each year between 1995 and 2017 interpreted by the authors from Statistics Sweden (2018).

As can be seen in Figure 7, the dominating material is concrete while wooden or steel frames are used less.

One dominating technique when building concrete frames is to use either prefabricated concrete beams, walls or other parts that are produced in industry and delivered to the building site by truck. The other dominating technique is to produce the frame at the building site, so-called site-cast, where the concrete is delivered by truck and then pumped into frames with prefabricated rebars and nets where the concrete solidifies. It is also prevalent to use a mix between the two specific techniques (Svensk Betong 2019c). In multi-story buildings, the most common technique is to use prefabricated concrete slabs and then fill these with concrete on-site to get an efficient and quick building process. It is also easy to install, e.g. plumbing in each concrete slab, which is then instilled to the whole floor (Svensk Betong 2019a).

4.1.5 Science

In the industry, the most significant offset takes place in the production of the cement and the calcination process where 60-65 % of the CO2 is released (Svensk Betong 2019b). The rest of the emissions come from different fuels used in the process. There is a potential to lower the CO2 emissions in the industry with foremost other materials in the mix of the concrete and the use of alternative binders such as fly-ash with a smaller CO2 footprint.

The concrete business has a significant environmental impact and the cement in the concrete accounts for around 8-10 % of the world's greenhouse gas emissions (Suhendro, 2014). However, Farfan *et al*. (2019) argue that it is around 5-8 % of the world's greenhouse gas emissions. Furthermore, Andrew (2018) states that the number is around 4 % of all the fossil fuels used in the world and pointing out that 70 % of the emissions from the cement industry since 1928 have occurred after 1990, which could show the immense impact concrete have had and will have. The concrete industry in Sweden, on the other hand, states that the cement production accounts for 3-4 % of the world's greenhouse gas emissions (Svensk Betong 2019b). One thing is for sure: the concrete industry emissions have gradually become bigger and bigger. The industry has never emitted more significant amounts of CO2 than now (2018), and it keeps rising (Andrew, 2018). Therefore, the focus in research is to lessen the climate impact of concrete as a construction material.

The most significant direct positive impact on CO2 emissions when it comes to concrete in the construction sector is to cut down the amount of Portland clinker. Portland clinker is a fine powder, produced by heating limestone and clay minerals in a kiln to form clinker. The clinker is then ground and gypsum is added (Nationalencyklopedin 2019a). The most CO2 intense part of producing Portland clinker is when the limestone is burnt in the oven. Therefore, the most common way to lower the CO2 emissions in concrete is to lower the clinker content by substituting the clinker with materials such as fly ash from coal-fired power plants, micro silica, pozzolanic materials and limestone powder or other ash types from domestic waste and bio-fuels and crushed glass waste. CO2 emissions could also be lowered if other fuels would be used in the process of making cement (Nielsen & Glavind, 2007). An example of this in Sweden is the company Skanska that will implement and offer green concrete in their buildings and to their customers (Betong 2019).

Moreover, Erlandsson *et al*. (2018) suggest other materials that could lower the CO2 emissions from concrete constructions. However, the alternatives to clinker do not come without considerations. Erlandsson *et al*. (2018) also show concerns for a shortage of fly ash because

of fewer and fewer coal plants and also bring up the problem with other types of ashes that are not CE-marked which is required by the Swedish standard.

Erlandsson *et al*. (2018) conducted a life cycle analysis (LCA) on a typical multi-story building with different frames as the volatile variable. Based on the LCA results, the Swedish Construction Federation came up with different solutions and examples on how developers can construct buildings with a smaller CO2 footprint, no matter which type of frame was used. The examples given are green concrete, using the best available materials with least climate impact, use renewable fuels on the building sites and for transports as well as educate the whole supply chain, foremost the purchasers.

4.1.6 Markets and user preferences

According to Statistics Sweden (**SCB**), 48,15 % of the Swedish households live in multi-story buildings (Statistics Sweden 2019c), which is indicated by Figure 8 below. SCB defines multi-story buildings as residential buildings with three or more storeys, including gallery buildings. The second biggest household type is single-family houses, which accounts for 44,26%, also seen in Figure 8 below. A single-family house is defined by SCB as detached one or two household houses as well as semi-detached houses, row-houses and linked houses. The rest of the households either live in special housing, which includes housing for students, elderly and disabled, or other types of housing. For 2,80% of the households, no data was available (Statistics Sweden 2019c).

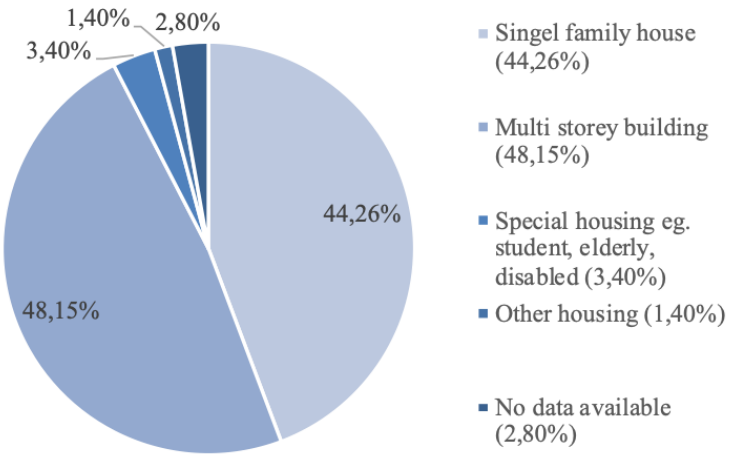

Figure 7. Distribution of Swedish households in different household categories in 2017 (Statistics Sweden 2019c).

Figure 8 indicates that the majority of Swedish households live in multi-story buildings today. However, almost as many live in single-family houses.

What determines where Swedish citizens choose to live has rarely been scientifically studied. However, pilot studies have indicated that the location and appearance of the apartment along with the living costs were among the most critical factors that determine where Swedish citizens choose to live (Andersson 2014; Forsberg Fierro 2017; TT 2017). Worth noting is that none concerns the choice of construction material.

A similar result was found in a study by Mark-Herbert *et al*. (2019) who found that the most critical factors that influenced WMC residents to buy their apartment were the location, size,

price and atmosphere of the apartment. The least important factor was the environmental properties of the building (*Ibid*.)

4.2 Niche-innovation

In this section, the niche innovation of WMBs is considered. First, the market share of WMBs are presented, then the construction process and properties of WMBs are briefly described. Furthermore, the binding of carbon dioxide in wood is presented. Lastly, collaborations within the WMBs sector is presented.

4.2.1 Market share of wooden multi-story buildings

From the year 2000 and onwards the number, WMBs have increased gradually in Sweden. Between 2015 and 2016 the number of new-built apartments in WMBs increased by 55%, resulting in approximately 3600 new apartments all over Sweden. In these figures, student housing and other types of special housing were not included. Nevertheless, the increase of apartments in WMBs correlates with an overall increase of newly built homes in Sweden. The increase means that the share of newly built WMBs of the entire newly built multi-story buildings in Sweden is constant on a level of 10% (Government Offices of Sweden 2018a).

The Swedish Federation of Wood and Furniture Industry (**SWFI**) collect data from some of their member organisations about the number of WMBs that are built in Sweden. SWFI conclude that in 2017, the number of WMBs in the building phase was at an all-time high at 3937 buildings (SWFI 2019). However, the percentage of WMBs of the entire multi-story buildings constructed remained constant at about 10%.

4.2.2 Construction of wooden multi-story buildings

WMBs can, just as concrete buildings, be built in different ways. There are three dominating techniques when it comes to building multi-story buildings of wood (Hurmekoski *et al*. 2015). The three techniques are;

1. platforms with poles or with massive elements;
2. post and beam construction and
3. modules.

In the platform technique, the load-bearing external walls are assembled on top of the floors, story by story. In the post and beam technique, the load-bearing structure is made out of massive supportive columns. When using this technique, the interior can be modified afterwards since the beams are the load-bearing structure, and no walls are needed for the load-bearing. The modular element technique is based on prefabricated rooms or modular elements where walls, windows, doors, bathrooms etcetera are prefabricated and assembled on-site (Hurmekoski *et al*., 2015). It is also possible to use all of the three types in different ways in one building. The most used technique is according to (Brege *et al*. 2017) the modular element technique, which stands for 90 % of the WMB constructions in Sweden.

There are both advantages and disadvantages connected to the modular technique. The disadvantages are the trade-off between customisation and mass production. Industrialisation also needs repetition to be cost-efficient, which means to build large buildings with small rooms, i.e. student apartments, hotels, etcetera, where the rooms look the same and are relatively small. This limits the types of buildings where modules can be used. Lastly, there are also high transport costs (Hurmekoski *et al*., 2015). One advantage of the modular technique is that the

time spent on building on-site decreases because of the high industrialisation and preparation beforehand, which could also potentially be more cost-efficient as it is possible to know all the costs in an early stage of the building process (Swedish Association of Local Authorities and Regions 2013).

4.2.3 Properties of Wooden Multi Storey Buildings

In this section, some of the concerns connected with WMBs are accounted for. The different concerns are many when building with wood, but in this thesis, the concerns of moisture, fire and acoustics are brought up since they are the most common in the discourse about WMBs.

Moisture

Wood is a hygroscopic material, which means that the material always tries to be in equilibrium with the moisture and temperature of the air. In other words, wood always tries to acclimatise with the surroundings (Svenskt Trä 2013). Therefore, the wood takes up and emits water when the moisture in the air changes or when the wood is in direct contact with water. Microorganisms can attack wood. Wet circumstances favour these attacks with long-time exposure and, therefore, wood should not be exposed to water except during short periods (*ibid*.). It is, thus, important not to expose the wood to the environment when building WMBs. Solutions are to use shelters during the building process and to protect the material during transportation. The high prefabrication rate of modular WMBs also ensures that the wood is dry, as it is constructed in a protected environment in the production facilities.

Fire

Since wood is a material that burns quickly, fire safety in WMBs has been widely debated in Sweden. Some critics see WMBs as having a more considerable risk of fire than concrete buildings, while others believe that WMBs and concrete buildings have the same risk of fire. Another concern is that the fire regulations in Sweden only concern personal safety and not the material aspects of the buildings. To not take the material aspects of the building into account could, according to some critics, make the insurances for WMBs much more expensive than for concrete houses. Another issue which concerns insurance companies are the sprinkler systems. The sprinkler systems needed in WMBs can leak and create moisture problems with microorganism in WMBs (Höghus av trä- Brandskyddsföreningen, Almedalen 2015 - YouTube 2015). Despite the critique, the regulations for the two different building systems are the same, stressing the importance of that people need to come out safely in case of fire (Swedish Association of Local Authorities and Regions, 2013). These two building systems also have the same system for the classification of fire safety (Stehn *et al*. 2008).

In contrast to the critique, Eriksson *et al*. (2016) conclude that the fire incidents in WMBs are less common than in concrete buildings. The lower occurrence is due to WMBs being newly built and having a higher fire safety standard than older buildings. However, other factors could also apply according to Eriksson *et al*. (2016), which these factors are is, however, not accounted for in the report.

Acoustics

Another concern is the acoustics of WMBs. Weight of construction material has a significant impact on the acoustic properties of a house. Since wood is a light construction material compared to concrete (Stehn *et al*. 2008; Träguiden 2019), it is essential to have a thick enough construction in WMBs, so that low frequencies (often steps in staircases and on floors) cannot travel through the building. Therefore joists of a WMB have to be at least 500 mm. Another

essential feature is to use mouldings between the joists, which lower the vibrations and low frequencies (Stening & Wall 2017).

There are different standards regarding acoustics in multi-story buildings, which applies to all construction materials. In the Swedish BBR regulation, the acoustic classes go from A-D, where A is the best (least noise), and D is the worst (more noise). Construction projects today most often aim for class B, which is often achieved in WMBs (Stehn *et al*., 2008; Träguiden, 2019).

4.2.4 Wood and the binding of carbon dioxide

The photosynthesis is the cornerstone of the Swedish forest and forest industry since it is the process that produces the wood needed for a BE to function. The sugars are used as building blocks and energy for the tree, and the oxygen is released out to the atmosphere (Hallsby 2013). As described in the introduction, one of the climate critical greenhouse gases is CO2. Hence, one way to capture CO2 is to plant trees or other photosensitising plants. The immaculate issue with trees is their relatively long lifecycles and the amount of biomass that can be produced, i.e. the significant amounts of CO2 they can absorb. When the wood is utilised and for example is used for buildings, it still serves as a carbon sink. Where the tree once stood, new trees can grow and capture more CO2. This can be connected to the climate impact of buildings, which is often discussed. One common technique to calculate the climate impact in the building sector is to perform an LCA. The LCA is a tool for analysing or declaring environmental impacts and the purpose of an LCA is to get an overview of the flows of the resources needed (SLU, 2019) to, for example, build a house. This type of analysis can, therefore, be used when comparing different building systems, such as WMBs with concrete buildings.

An LCA has been made by Erlandsson *et al*. (2018). In the report, Erlandsson *et al*. (2018) have not used the CO2 sequestration in their LCA. Erlandsson *et al*. (2018) explain how CO2 sequestration could affect the LCA. Since the wood "captures" CO2 and if one assumes that forestry in Sweden is sustainable, i.e. the forest grows more cubic meter than is harvested, the wood becomes a carbon sink.

Because of the life cycle length of houses, new forests can grow where the utilised forest to build the houses used to be. Therefore, if Erlandsson *et al*. (2018) include the carbon sink aspect on wood, the house example of Erlandsson *et al*. (2018) becomes climate positive, i.e. binds more CO2 than it produces during the house's life cycle. This should be compared to the concrete house in the LCA example by Erlandsson *et al*. (2018) that cannot sequestrate the same amount of CO2 since it is not made of a material that is as renewable as wood.

It should be said that an LCA only mirrors the system limitations set in the specific LCA (SLU 2019). In other words, LCA analyses with different system limitations can give different results even though the same phenomenon is studied. It is essential to understand that there is no correct answer when performing an LCA, so one has to do a critical review of the LCA (*ibid*.). However, the Erlandsson *et al*. (2018) example can be the right way of showing the positive aspects of building in wood but should not be seen as the absolute truth.

Some other factors should be taken into consideration when talking about sustainable forests and forestry, which are directly connected to building with wood. An example is the loss of biodiversity when using the system used in Sweden where the homogenising of the forest, i.e. only planting one type of species, has contributed to the loss of biodiversity (Weslien & Widenfalk 2014). In this study, the analysis does not go any deeper than notifying that biodiversity loss could be a future problem for the industry.

4.2.5 Forest industry collaborations

As a way to promote wooden products, several industry collaborations within the forest industry have been established in Sweden. Members of the Swedish Forest Industries Federation are promoting wood as a construction material through a sub-organisation called Swedish Wood. Swedish Wood is working with spreading information about how to use wood in constructions, establishing standards and participating in research projects connected to wood construction. Moreover, Swedish Wood also organises a competition for architects who design wooden buildings (Svenskt Trä 2019).

Another industry collaboration is the secretariat for Swedish Wood Buildings (Svenskt Träbyggnadskansli), which is a collaboration between Swedish Wood and the Federation of Wood and Furniture Industry. Swedish Wood Buildings promotes using wood in the building sector in Sweden and focuses primarily on multi-story buildings, public buildings and more massive road bridges. Their primary focus is to promote building with wood, but they also offer expertise and support to any building projects made of wood in Sweden (Svenskt Träbyggnadskansli 2019).

Most recently several actors within the forest industry have also joined forces and initiated an information campaign called “Swedish Forest” (Svenska Skogen). The campaign aims at increasing the knowledge about Swedish forests and forestry in the urban population of Sweden and is planned to be a long term investment (Svenska Skogen 2019).

4.3 Socio-technical landscape

In this part, the factors in the ST-landscape that influence the ST-regime and niche innovations of the multi-story buildings sector in Sweden are presented.

4.3.1 Destabilizing factors

Destabilising factors are factors in the ST-landscape that challenge the ST-regime, i.e. current practices and ways of thinking, and create windows of opportunity for niche innovations to enter a market.

Climate change

As stated in the introduction, the worlds average temperature has increased rapidly due to human activities, causing changes in the climate around the globe (Intergovernmental Panel on Climate Change, 2018, p. 8). Therefore, actions against further temperature increases need to be taken, which is being done on a both supranational and national level (Intergovernmental Panel on Climate Change, 2018).

Sweden has set a target of becoming carbon neutral no later than 2045 (Swedish Environmental Protection Agency 2018) and becoming carbon neutral means that Sweden aspires to achieve net-zero carbon dioxide emissions. After 2045 Sweden aims to have negative carbon emissions, meaning that Sweden should have at least 85% fewer emissions in 2045 compared to the emissions in 1990 (Government Offices of Sweden 2017; Swedish Environmental Protection Agency 2018).

The target was agreed on with a broad political majority in the Swedish parliament in 2017 and came into force on January 1st, 2018. The Swedish Environmental Protection Agency (2019) has identified that the significant challenges to reach the goal exist in the industry and transport sector, who stand for two-thirds of the total Swedish greenhouse gas emissions. Within the

Swedish industry sector, 80% comes from the primary industry, which is made up by the iron and steel industry, the cement industry and refineries. Moreover, carbon storage must be developed in order to reach the 2045-goal (Swedish Environmental Protection Agency, 2019).

Five areas have been identified where the government needs to act forcefully, to reach the goals:

- Support electrification of transports and the industry
- Implement a strategy for BE and use of biomass
- Engage the financial market in the climate work
- Increase the circularity and the resource efficiency
- Develop and complement the pricing setting of carbon emissions (Swedish Environmental Protection Agency, 2019).

Besides, Sweden should also engage in minimising carbon emissions outside the borders of Sweden. Primarily by having ambitious targets in negotiations, act as an inspiration for other countries and minimise the effect of Swedish citizens' contribution to carbon emissions in other parts of the world (Swedish Environmental Protection Agency 2019)

The construction sector and climate change

According to the Swedish Environmental Protection Agency (2019), the construction sector in Sweden, which includes both buildings and infrastructure, emit approximately 10 million tons of greenhouse gases every year. The sector has the potential to decrease its current carbon emissions by 50% with the techniques that are used today. However, the construction sector also offers the potential to store carbon in wooden constructions according to the Swedish Environmental Protection Agency (2019), which is also promoted by the government.

The Swedish government promoting wood

Since WMBs were legalised again in 1994, the Swedish government has been promoting wood as a construction material. In 1997 the Swedish Government launched an R&D and marketing programme called "Wood, Construction and Furniture Program" together with the industry. This programme was aimed at boosting the wood product sector and increase the prefabrication. After this, several other programmes have followed with similar aims (Table 7) (Hemström *et al*., 2012).

Table 7. Examples of programmes initiated by the Swedish government that promote construction in wood

Name (Year)	Description
Wood Cluster program (2002-2005)	
National Strategy on Wood Construction (Nationella träbyggnadsstrategin) (2004-2008)	Aimed at promoting the construction of WMBs and create an opportunity for wood to compete with other building materials which were supported when wood was prohibited. Based on a will to support environmentally friendly materials (Hemström *et al.,* 2012).
Trästad 2012 (2009-2012)	Trästad 2012 was launched to continue the work done during the National Strategy on Wood Construction (Pettersson, 2009). In the program representatives from the industry, 16 municipalities and four county administrations participated to promote building with wood in city environments (Hemström *et al.,* 2012).
Collaboration program for Circular and biobased economy	Within the programme several main areas have been identified and building with wood is one of them. Round table discussions have been

(Samverkansprogrammet för Cirkulär och biobaserad ekonomi)	held to identify barriers and find solutions to challenges for increased use of wood in construction (Government Offices of Sweden 2018a p. 14).
National forest programme (Nationella skogsprogrammet) (2018-)	The new strategy for the Swedish forest sector contains five focus areas, and nnovation and refined forest raw materials are amongst them. WMBs are part of this focus area and an increased industrial building with wood is seen as a solution to sustainability challenges (Government Offices of Sweden 2018a p. 14).
Nordic collaboration for increased industrial construction in wood (Nordisk samverkan inom industriellt träbyggande) (2018-2020)	The Swedish government initiated a collaboration with the Nordic Minister Council, with the aim to develop industrial construction with wood in the Nordic countries. The project will identify and analyse barriers and challenges for the Nordic countries to increase the industrial construction with wood and eventually come up with an action plan to handle these challenges (Government Offices of Sweden 2018a p. 14)).

As seen in Table 7, the Swedish government has initiated several programmes that partly or wholly aims at increasing construction with wood. These programmes have been initiated during several different governments, with different political interests, which can be interpreted as the political will to increase the building of WMBs being strong in Sweden.

Population increase and the need for new housing

The Swedish population has increased steadily for several decades, reaching 10,2 million people in 2018 (Statistics Sweden 2019a). According to Statistics Sweden, the Swedish population is predicted to pass 11 million in the year 2028 and 12 million in the approximately year 2050 (Statistics Sweden 2018), which requires more housing.

In Sweden, the Swedish National Board of Housing, Building and Planning (Boverket) is responsible for analysing the housing market. According to Boverket, the need for new housing is estimated to be 66 900 housings per year from 2018 up until 2025. However, as the level of production of new housing has been insufficient from 2012 and onwards, Boverket states that there is an increased need for new housing up until 2020. The insufficient housing production means that until the year 2020, 93 000 new housing units would need to be built per year. After that, 51 000 housings per year are needed to be built until 2025 (National Board of Housing, Building and Planning 2018a).

According to Boverket, the need for new housing in Sweden is historically high, due to the anticipated population increase:

"The coming three years there is almost a need for a new Uppsala or a large Linköping to be built each year" (National Board of Housing, Building and Planning 2018a p. 27).

For the housing industry, this means that it has to triple its production rate from 25 000-30 000 newly produced housings per year to the required levels. The tripled production rate is seen as a challenge by Boverket, as it will require increased resources and knowledge in the housing industry, which have previously indicated that there is already today a lack of both knowledge and resources (National Board of Housing, Building and Planning, 2018b).

4.3.2 Stabilizing factors

Stabilising factors in the ST-landscape are factors that help uphold the dominant ST-regime. In the case of multi-story buildings in Sweden, stabilising factors are factors that support the steel and concrete constructions rather than WMB.

Competition about the forest resource

Every year the Swedish forests grow with approximately 120 million forest cubic meters, while the total harvesting level is approximately 93 million forest cubic meters. Even though all forest cubic meters that grow each year are not harvested, a debate about if the forest resource can offer enough raw material for all potential uses has come up. In this debate, representatives from the Swedish Forest Agency (Skogsstyrelsen), among else, argue that the harvesting levels are already as high as they can be (Johansson, 2018).

The forest resource in Sweden has primarily been used for timber and pulp, but recently, new usage areas of the forest resource have been suggested. These uses include, for example, biofuels and bioplastics (Nilsson 2018). Besides, there are large areas of forest in Sweden which are protected and not available for harvesting (Johansson, 2018). These protected forests are essential for biodiversity and ecosystem services like water purification and recreation (Nilsson 2018; Swedish Environmental Protection Agency 2019). Because of the increased demand on what the forest resource should deliver scientists along with representatives from the forest industry, the Swedish Forest Agency and the Swedish Environmental Protection Agency argue that the forest resource is limited and that there is a possibility that it will not be able to fulfil all future needs (Axdorff, 2018; Johansson, 2018; Nilsson, 2018; Swedish Environmental Protection Agency, 2019).

5 Empirics

In this section, the empirics of this study are presented. Firstly, background information about the respondents is presented. Then how the respondents perceive carbon storage of forests, FBB and WMBs follow.

5.1 Respondent background information

The survey data consists of 204 responses from Swedish citizens between the ages of 18 to 84 years and replying took on average 7 minutes and 37 seconds. In total, 1,4% of the visitors that visited IKEA Uppsala on the 8th and 9th of December 2018 answered the survey. Table 8 shows the number of respondents who assigned themselves to each background information category.

Table 8. Number and percentage of respondents assigned to each background information category

Respondent background information	Category	Percent
Gender	Female	55,9%
	Male	43,1%
	Other	1,0%
	Total	**100,0%**
Age category	18-39	39,7%
	40-64	44,6%
	65+	15,7%
	Total	**100,0%**
Which of the following best suits your current area of residence?	Urban	58,8%
	Suburb	17,2%
	Rural	24,0%
	Total	**100,0%**
Do you own more than one hectare (10 000m2) of land or forest?	No	91,2%
	Yes	8,8%
	Total	**100,0%**

As shown in Table 8, the majority (55,9%) regarded themselves as females, while the rest regarded themselves as males (43,1%) and as other (1%). In terms of age, 39,7% were between 18-39 years old, 44,6% were between 40-64 years old, and 15,7% were 65 years or older. The vast majority of the respondents stated that they live in an urban area (58,8%) and a minority lived in either a rural (24,0%) or suburban (17,2%) area. Most of the respondents did not own more than one hectare (10 000 m2) of land or forest (91,2%). The majority of the respondents answered the survey in Swedish (96,02%), while the rest answered in English (3,98%). Of all respondents, 89,71% were of Swedish nationality.

The means for all questions asked in this survey are presented in Appendix VI.

5.2 Familiarity with carbon storage in forests

Of the total 204 respondents, 74 were not familiar with how forests store carbon, while 130 respondents were familiar. Table 9 indicates what percentage of the population was and was not familiar with carbon storage.

Table 9. Frequency distribution table of how the respondents perceived their familiarity with how forests store carbon

I am familiar with how forests store carbon	Percent
No (Strongly disagree, Disagree, Mildly disagree, Mildly agree)	36,3
Yes (Agree and Strongly agree)	63,7
Total	**100,0**

As mentioned in the method chapter, a six-point Likert scale was used to capture variation in the perceptions of the consumers (1=Strongly disagree, 2=Disagree, 3=Mildly disagree, 4=Mildly agree, 5=Agree and 6=Strongly agree). The respondents that agreed or strongly agreed to the statement presented in Table 9 were regarded as being familiar with WMBs, while the rest was not. Mildly agree was not included in the yes-option because the moderate answer alternatives of mildly agree and mildly disagree were included in the survey instead of a "do not know"-option. Hence the respondents that answered mildly agree to this question are seen as they are not entirely sure about the concept of carbon storage.

As this analysis is made of a small sample, that has been selected through convenience sampling; it is not possible to generalize the results for a larger population. The information in Table 9 should, therefore, only be seen as a description of the respondents of the survey used in this study.

5.3 Socio-political acceptance of the low carbon transition of forest-based bioeconomy

Table 10 shows the percentage of respondents who claimed they knew the meaning of FBB. Of the 204 respondents, 59 of them knew the meaning of FBB, while 145 of them did not.

Table 10. Perceived understanding of the concept of forest-based bioeconomy among the respondents

I know the meaning of forest-based bioeconomy	Percent
No (Strongly disagree, Disagree, Mildly disagree, Mildly agree)	71,1
Yes (Agree and Strongly agree)	28,9
Total	**100,0**

Similar to section 5.2, the respondents that agreed or strongly agreed to the statement presented in Table 10 were regarded as they knew the meaning of FBB, while the rest was not.

In Figure 9, the frequency distribution of the respondent's perceptions of FBB divided into answer categories is shown in a bar chart. A positive percentage indicates that the respondents agree with the statement to some degree, while a negative percentage indicates that the respondents disagree.

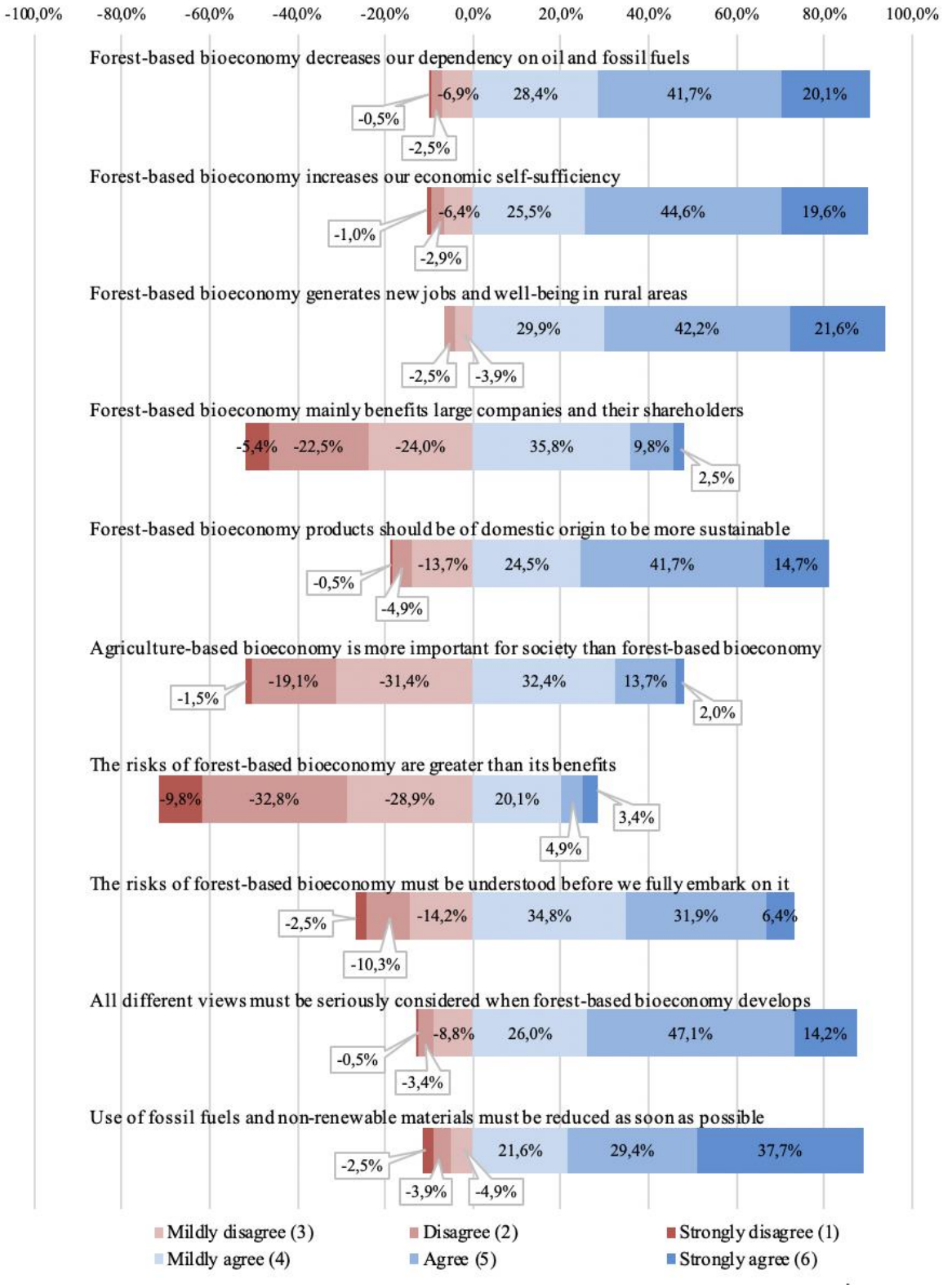

Figure 8. Frequency distribution bar charts of how the respondents perceived forest-based bioeconomy.

As can be seen in Figure 9, the majority of the respondents agree to some degree to the statements that FBB decreases our dependency on oil and fossil fuels (90,2%), increases our economic self-sufficiency (89,7%) and generates new jobs and well-being in rural areas (93,6%). Approximately half of the population believe that FBB mainly benefits large companies and their shareholders (48,0%), while the other half disagrees with this statement

(52,0%). The same figures are found for the question about agriculture-based BE, where 48,0% agree that agriculture-based BE is more critical for the society than FBB, while 52,0% disagree.

The majority of the respondents also agree that FBB products should be of domestic origin to be more sustainable (80,9%) and that the risks of FBB are not greater than its benefits (71,6%). However, most of the respondents do agree that the risks of FBB must be understood before we fully embark on it (73,0%) and that all different views must be seriously considered when FBB develops (87,3%). Lastly, the vast majority also agree that the use of fossil fuels and non-renewable materials must be reduced as soon as possible (88,7%).

5.3.1 Social acceptance of forest-based bioeconomy and familiarity with the concept

As 71,1% of the respondents were not familiar with FBB, the answers were also analysed based on the respondent's familiarity with FBB. The respondents were, therefore, divided into two groups. One group was the respondents who were familiar with FBB, and the other group was made up by the respondents who were not familiar with FBB. Similar frequency distribution tables were computed as in Figure 9 above, which can be seen as a whole in Appendix II. However, no or only minor differences in answer distributions between the two groups were found for the following questions:

- FBB products should be of domestic origin to be more sustainable
- Agriculture-based BE is more important for society than FBB
- Use of fossil fuels and non-renewable materials must be reduced as soon as possible

For the remaining survey questions, the differences between the groups were more significant and, hence, these questions are presented in frequency distributions bar charts divided into the two sub-groups in Figure 10 and 11 below.

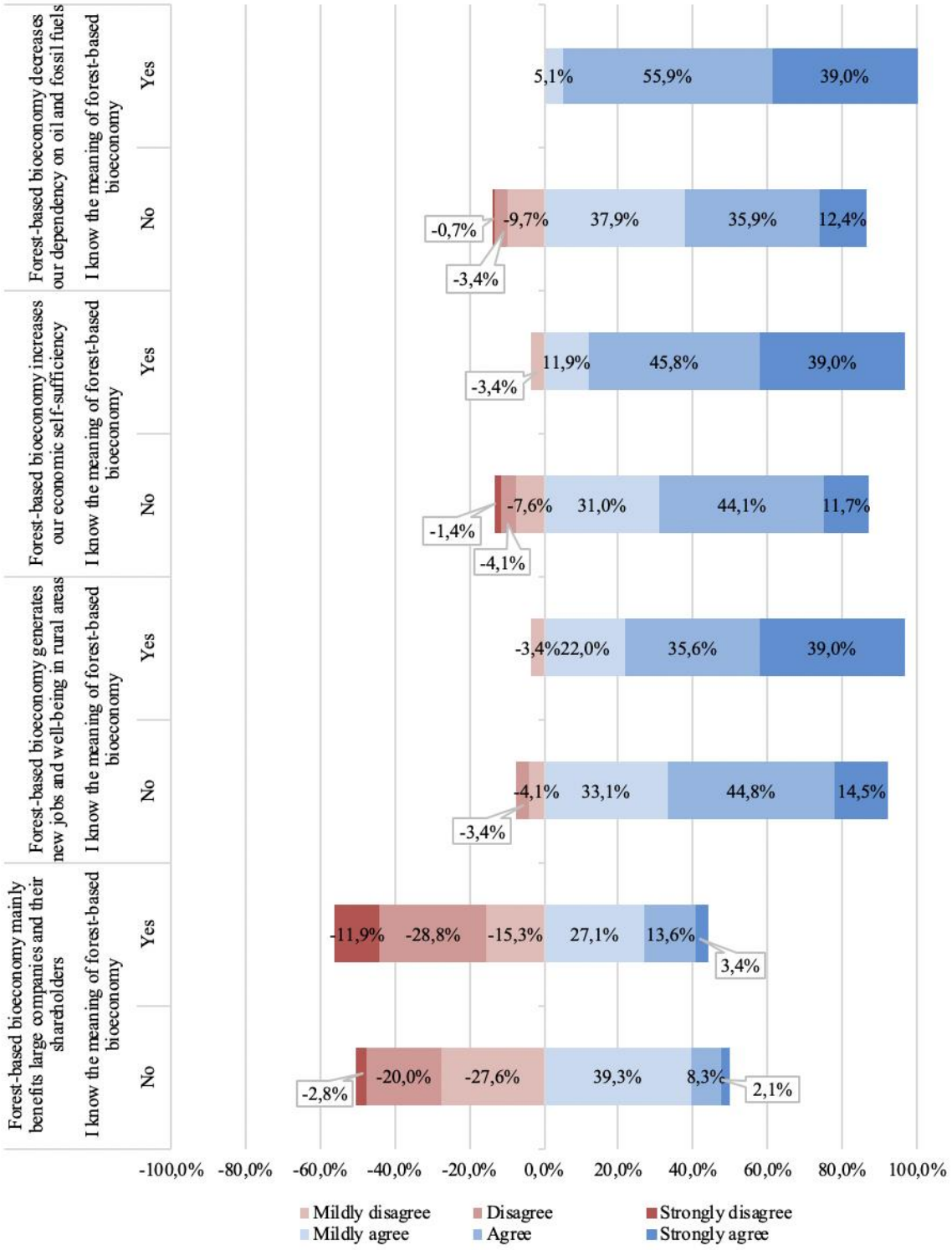

Figure 9. Part I of the frequency distribution bar chart of how the respondents perceived forest-based bioeconomy.

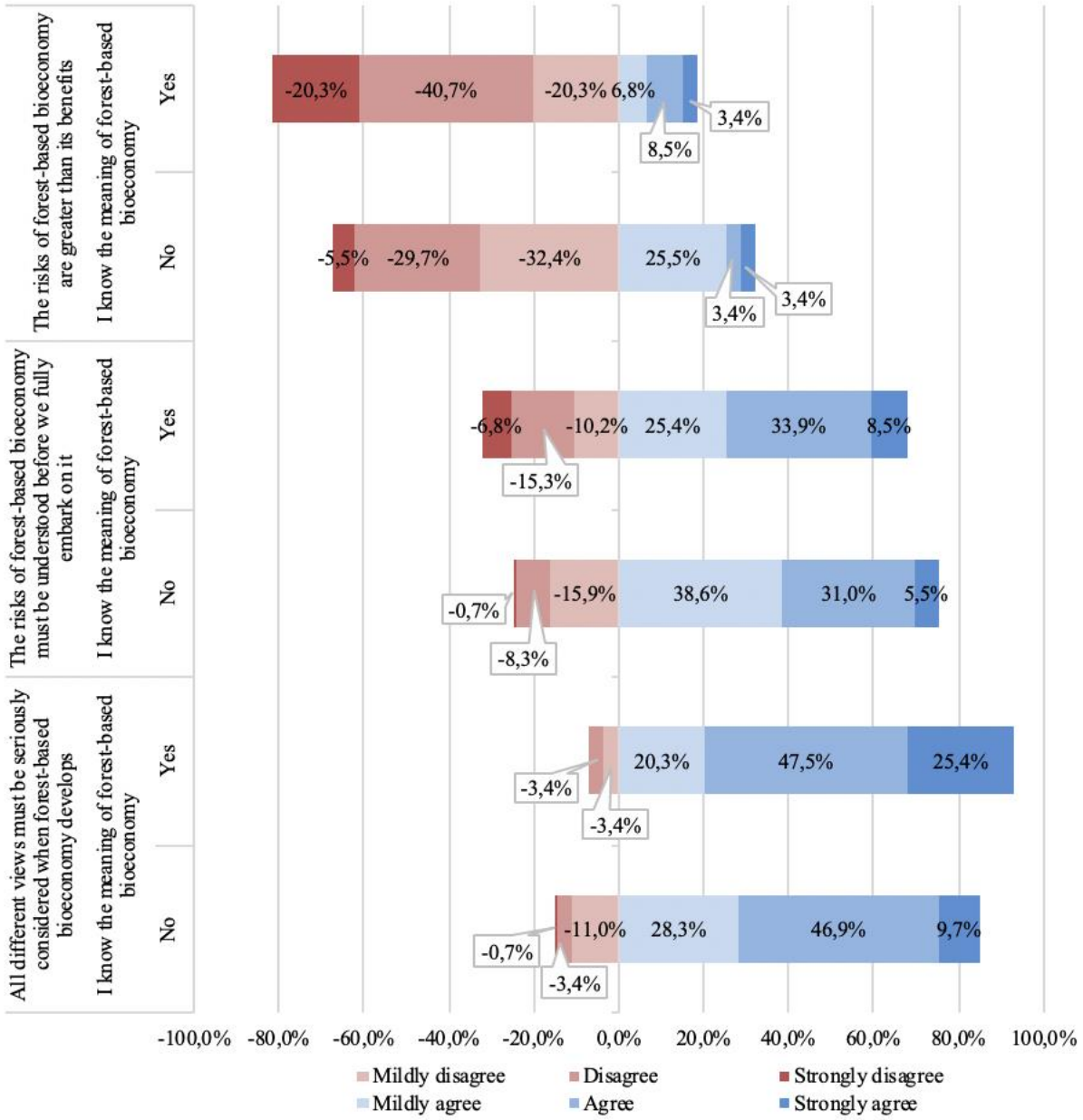

Figure 10. Part II of the frequency distribution bar chart of how the respondents perceived forest-based bioeconomy depending on if they knew the meaning of forest-based bioeconomy or not.

For each question, two bars are shown in Figure 10 and 11. One represents how the respondents who knew the meaning of FBB perceived the question, while the other represents the perceptions of the respondents that did not know the meaning of FBB. In both figures, a negative percentage indicates that the respondents disagreed with the statement to some degree, while a positive percentage indicates that the respondents agreed.

The analysis indicates that the group who knew the meaning of FBB was in general more positive towards this LCT than the group that did not know. All of the respondents in the group who knew the meaning of FBB agreed to some degree that FBB decreases our dependency on oil and fossil fuels. Similarly, almost all of this group agreed that FBB increases our economic self-sufficiency (96,6%). The same numbers for the group that did not know the meaning of FBB was 86,2% and 86,9% respectively. The differences were, therefore, not substantial, but the distribution of the degree of agreement differs largely between the groups. The same is valid

for the statement about FBB generating new jobs and well-being in rural areas. The group that knew the meaning of FBB agreed by 96,6%, while the other grout agreed by 92,4%. The first group did, however, choose the option of "strongly agree" to a more considerable extent than the other group which choose more moderate answers.

A more substantial part of the group that did not know the meaning of FBB agreed to the statement that FBB mainly benefits large companies and their shareholders (49,7%) than the group that knew the meaning (44,1%). However, most of the respondents in both groups disagreed to this statement, although by a small majority. The group who knew the meaning of FBB were more positive towards the risks of FBB, with 81,4% disagreeing with the statement that the risks of FBB are more significant than its benefits. The same figure for the other group was 67,6%. The majority of both of the groups did also agree that the risks of FBB must be understood before Sweden fully embarks on it. The group who knew agreed by 67,8%, while the other group agreed by 75,2%. Lastly, a more significant part of the group that knew the meaning of FBB agreed to the statement that all different views must be seriously considered when FBB develops (93,2%) than the other group (84,8%).

5.4 Perceptions about niche innovations and the socio-technical regime in multi-story buildings in Sweden

Respondents' perceptions of multi-story buildings in wood serve as an example of a niche innovation. Most multi-story buildings in Sweden are built of steel and concrete, which is the conventional way of building (the ST-regime). Respondents perceptions about these two building materials are presented.

5.4.1 Familiarity with wooden multi-story buildings

Of the 204 respondents of this study, 92 of them were not familiar with wooden multi-story buildings, while the remaining 112 respondents were. Table 11 show the percentage of respondents who were and were not familiar with wooden multi-story buildings.

Table 11. Perceived familiarity with wooden multi-story buildings among the respondents

I am familiar with wooden multi-story buildings	Percent
No (Strongly disagree, Disagree, Mildly disagree, Mildly agree)	45,1
Yes (Agree and Strongly agree)	54,9
Total	**100,0**

Similar to section 5.2 and 5.3, the respondents that agreed or strongly agreed with the statement presented in Table 11 were regarded as they knew the meaning of forest-based BE, while the rest was not. As mentioned previously in section 5.2 and 5.3, no general conclusions can be drawn for the total Swedish population because of the limited sample size and the sampling method.

5.4.1 Market acceptance of wooden multi-story buildings in comparison to steel and concrete buildings

In Figure 10, a bar chart of the frequency distribution of the respondent's answers per question is shown in per cent. A positive percentage indicates that the respondents agree with the statement placed above the individual bar chart to some degree, while a negative percentage indicates that the respondents disagree.

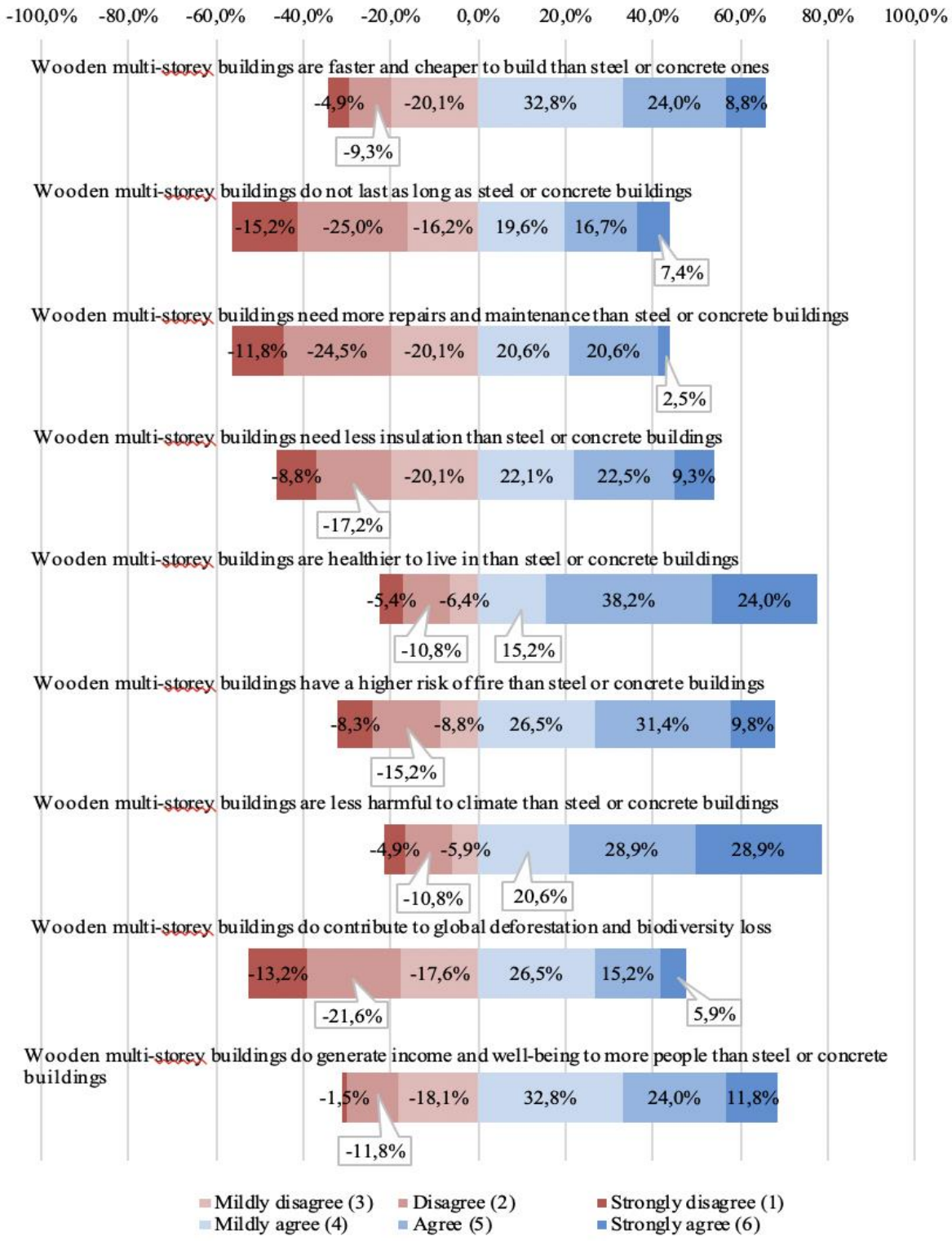

Figure 11. Frequency distribution bar charts of how the respondents perceived wooden multi-story buildings in comparison to steel and concrete ones.

Figure 10 shows how the respondents have answered the questions based on the degree of agreement/disagreement. Here a summary of how large part of the respondents agreed and disagreed to the statements follows. The degree will be analyzed further in chapter 6.

The majority of the respondents agree with the statement that WMBs are faster and cheaper to build than steel and concrete ones (65,7%). The majority also believes that WMBs last as long as the steel and concrete ones and that they do not need more repairs and maintenance (56,4% respectively). In terms of insulation, most of the respondents agree with the statement that WMBs need less insulation than steel or concrete buildings (53,9%). Most of the respondents also believe that WMBs are healthier to live in (77,5%) and less harmful to the climate (78,4%). However, they also believe that WMBs have a higher risk of fire (67,6%) than steel or concrete ones. Approximately half of the respondents agree with the statement that WMBs contribute to global deforestation and biodiversity loss (47,5%). Lastly, the majority also believes that WMBs do generate income and well-being to more people than steel and concrete buildings.

5.4.2 Market acceptance of wooden multi-story buildings based on familiarity of these buildings

As 45,1% of the respondents were not familiar with WMBs, further analysis was made where the respondents were divided into two groups based on their familiarity with WMBs or not. For all questions but one of the two groups had different perceptions of WMBs. The question where the two groups answered similarly was if wooden multi-story buildings have a higher risk of fire than steel or concrete buildings.

The result of this question is not presented any further in this section but can be seen in Appendix II. The other survey questions are presented in frequency distributions bar charts in Figure 11 and 12 below.

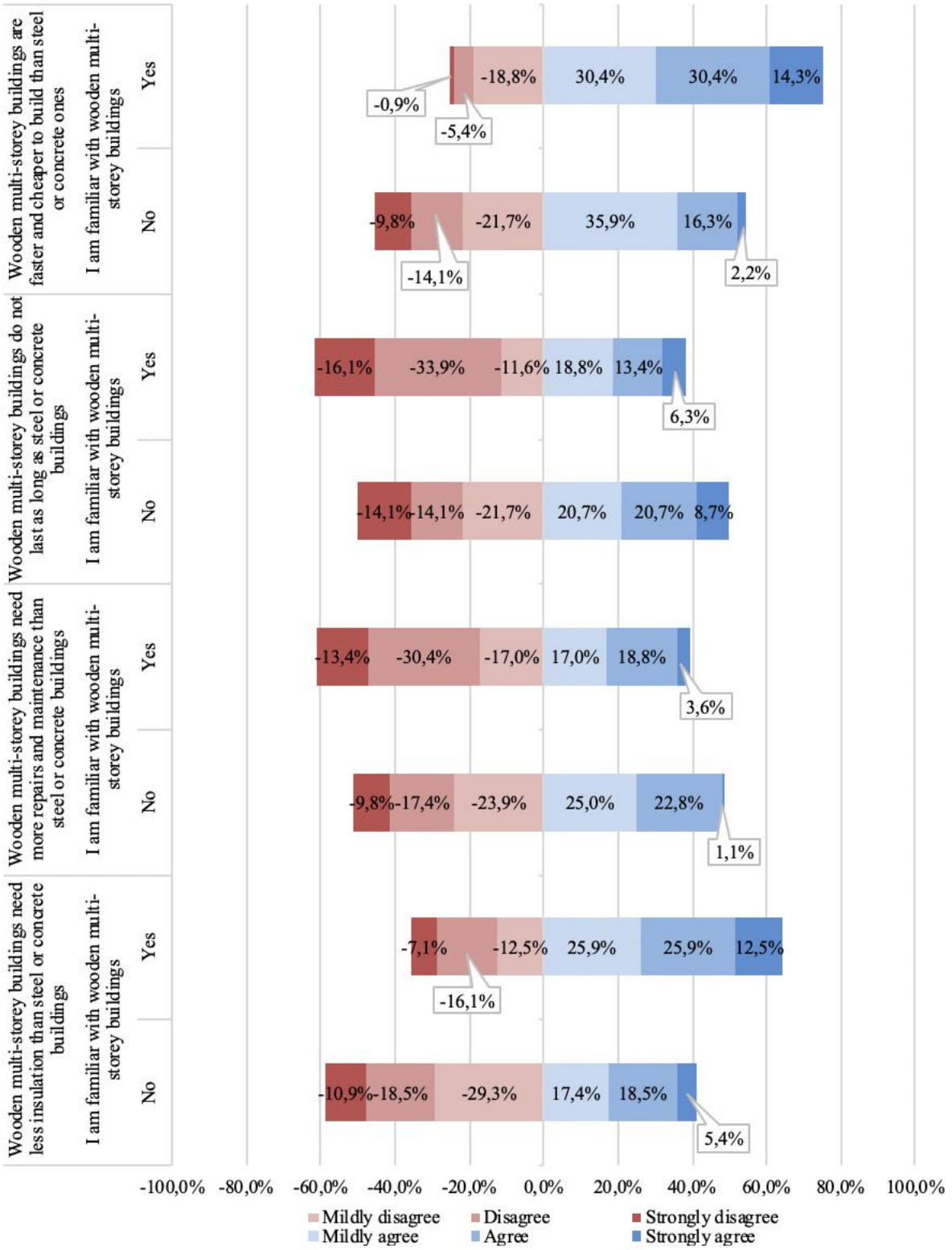

Figure 12. Part I of the frequency distribution bar chart of how the respondents perceived wooden multi-storey buildings depending on if they were familiar with wooden multi-storey buildings or not.

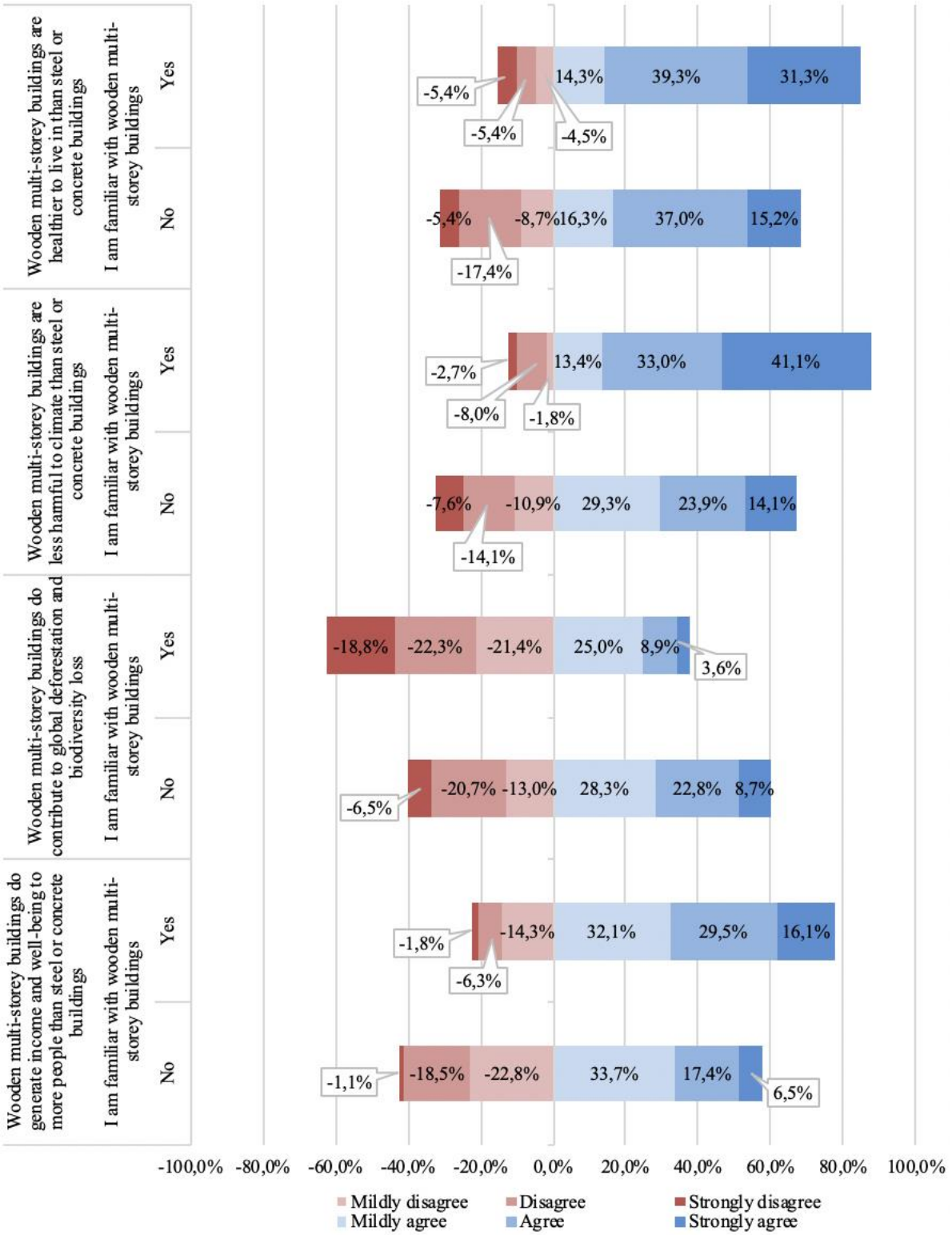

Figure 13. Part II of the frequency distribution bar chart of how the respondents perceived wooden multi-storey buildings depending on if they were familiar with wooden multi-storey buildings or not.

For each question, two bars are shown in Figure 11 and 12. One represents how the respondents who were familiar with WMBs perceived the question, while the other represents the perceptions of the respondents that were not familiar with WMBs. In both figures, a negative percentage indicates that the respondents disagreed with the statement to some degree, while a positive percentage indicates that the respondents agreed.

The analysis indicated that the respondents who were familiar with WMBs were more positive towards them. The familiar group agreed with the statement that WMBs are faster and cheaper to build than steel and concrete ones by 75% in comparison to the unfamiliar group were only 54,3% agreed. The majority of the familiar respondents also believe that WMBs do last as long as the steel and concrete ones (61,6%) and that they do not need more repairs and maintenance (60,7%). The same numbers for the respondents that were unfamiliar with WMBs were 50% and 51,1% respectively. In terms of insulation, most of the respondents who were familiar with WMBs agree with the statement that WMBs need less insulation than steel or concrete buildings (64,3%), while only 41,3% of the unfamiliar respondents agreed.

Both groups believe that WMBs are healthier to live in. However, a more significant part of the group that were familiar agreed (84,8%), than the group that was unfamiliar (68,5%). Similarly, the majority of the respondents also agree with the statement that WMBs are less harmful to the climate (87,5% and 67,4% respectively). Most of the respondents that were unfamiliar with WMBs agreed to the statement that they contribute to global deforestation and biodiversity loss (59,8%), while the same figure for the group that was familiar was 37,5%. Lastly, both groups also believe that WMBs do generate income and well-being to more people than steel and concrete buildings. However, the familiar group agreed to a more considerable extent (77,7%) than the unfamiliar group (57,6%).

The empirical findings presented here is further analyzed in the next chapter.

6 Analysis

This chapter addresses the research questions stated in chapter one, based on the theoretical framework and the empirical data. Since the carbon storage of forests is the foundation of why FBB is an LCT, the respondents' familiarity with carbon storage in forests is firstly analysed. The first research question is answered in section 6.1 were socio-political acceptance, and public perceptions about forest-based bioeconomy are discussed. The second research question is answered in section 6.2, where market acceptance and consumers perceptions of WMBs are brought up. Lastly, the third research question about enabling and hindering factors for implementing FBB and WMB in the ST-regime of multi-story buildings in Sweden is answered in section 6.3.

6.1 Socio-political acceptance of forest-based bioeconomy

The first research question was aimed at answering how a group of Swedish citizens perceive the low-carbon transition of forest-based bioeconomy. Therefore, the respondents were asked about how familiar they were with how forests store carbon. This study indicate that a majority (63,7 %) of the respondents are familiar with how forest store carbon. This question is maybe one of the most important to understand in the discourse about BE and the low-carbon transitions since the foundation of the BE is to replace non-renewable feedstock with renewable feedstock (Priefer *et al*., 2017, p. 1). One of the drivers within the public towards an LCT for transportation that Geels (2012) conclude is peak oil and climate change. Mustalahti (2018) argues that the citizens need to be engaged in these efforts, and this requires an understanding of the problems.

The questions about low-carbon transitions represented by the FBB several exciting patterns were shown in the empiric material. In the respondent group, the knowledge about FBB was low, and only 28,9 % knew the meaning of the term FBB. Those who knew the meaning of FBB were, in general, more positive towards FBB as a concept compared to those who did not know the meaning.

The answers about FBB were spread out over the whole scale. The questions asking if FBB decreases the Swedish dependency on oil and fossil fuels increases Swedish economic self-sufficiency and generates more looked reasonably alike. About 20 % in each question strongly agreed, around 40 % agreed, and around 30 % had one of the more negative answers on the scale. A question that divided the group was the question if FBB mainly benefits large companies and their shareholders. Approximately 50 % disagreed with this statement, and 50 % agreed with it. In comparison to the other questions, the positive ideas of the concept of FBB should be more significant. However, on the other hand, no rating of the importance of the questions was done with the survey results.

The questions whether the FBB products should be of domestic origin to be more sustainable, the respondents answered positively in the vast majority. Connecting this to the question about generating jobs and well-being in rural areas could be an enabling factor. The risks related to FBB was considered smaller by the respondents than the benefits. Despite this, the respondents thought that the risks must be considered before embarking on the FBB.

Whether or not the respondents thought the agriculture-based economy was more important than FBB, the answers were evenly distributed over the positive and negative side with approximately 50 % on each side. A vast majority thought that all different views must be

considered before embarking on FBB. Nonetheless, it is possible that the respondents could not fully evaluate what "all views" included, which might explain why the replies were on the more extreme ends of answering, i.e. strongly disagree or strongly agree.

The majority seems to think that reducing fossil fuels and non-renewable energy sources is of great importance as a large share of the respondents answered "strongly agree".

6.2 Market acceptance of wooden multi-story buildings

The second research question was aimed at answering how a group of Swedish consumers perceive the niche innovation of multi-story buildings with a mostly wooden frame in comparison to the dominant socio-technical regime of concrete and steel constructions in Sweden. Approximately half of the respondents were familiar with WMBs (54,9%). The respondents that were familiar with WMBs were generally more positive towards WMBs than the respondents that were not familiar with WMBs. A majority (65,7%) of the respondents agree to some degree with the statement that WMBs are faster and cheaper to build than steel and concrete ones. As WMBs can be prefabricated to a more significant extent than their steel and concrete counterparts, the construction time on the building site might be shorter. However, the prefabricated modules still have to be built off-site. If WMBs are cheaper to build or not compared to steel or concrete remains unclear. It is also unclear whether WMBs

a) last as long;
b) need more repairs and maintenance;
c) are healthier to live in;
d) contribute to global deforestation and biodiversity loss or;
e) generate income and well-being to more people;

then steel and concrete buildings. No studies were found to compare these perceptions with and so it is not possible to say if the public perceptions are in line with previous research or not.

Regarding sound isolation, steel and concrete buildings seem to have an advantage over WMBs, as the weight has an impact on sound transmission and WMBs are not as heavy as steel and concrete buildings (Stehn *et al*., 2008; Träguiden, 2019). However, no information about temperature isolation properties of WMBs in comparison to steel and concrete buildings were found in the literature. Mixed answers were found among the respondents, as their answers were distributed over all answer categories.

The main reason why a ban of WMBs was introduced in Sweden in the 19th century was because of the risk of fire (Hemström *et al*., 2012). The risk of fire is still debated in the multi-story buildings industry (Swedish Association of Local Authorities and Regions 2013; Höghus av trä- Brandskyddsföreningen, Almedalen 2015 - YouTube 2015). However, according to a report by Eriksson *et al*. (2016), fire incidents are less common in WMBs than in concrete buildings as they are newly built and have high fire safety standards. Consumers also have different views on this matter as 67,7 % believe that WMBs have a higher risk of fire, while the rest does not. Worth noting is that there were no differences between the distributions of answers between the group of respondents that were familiar with WMBs and the group that was not. This result is in line with the results found by Hemström *et al*. (2011), who found that Swedish architects tend to choose concrete before wood as construction material, based on the fire properties of wood.

Nearly 80% (78,4%) of the respondents agree with the statement that WMBs are less harmful to the climate than steel and concrete ones. Some authors like Erlandsson *et al*. (2018) claim that WMBs have a lower climate impact than steel and concrete buildings based on LCAs. However, whether the LCA results point to WMBs being less harmful to the climate depends on which factors are included in the LCA analysis.

In the next section, the empirical findings are analysed to identify enabling and hindering factors for establishing WMBs in the ST-regime.

6.3 Enabling and hindering factors of forest-based bioeconomy

This study is aimed at identifying enabling and hindering factors connected to SA for implementing FBB and establishing WMBs in the ST-regime of multi-story buildings in Sweden today. Here these enabling and hindering factors are identified.

6.3.1 Enabling factors

This study identifies several enabling factors connected to SA for establishing FBB in the form of WMB in the ST-regime. These are presented below in Table 12.

Table 12. Enabling factors for establishing forest-based bioeconomy in the socio-technical regime of the housing system in Sweden

Area	**Enabling factor**
Climate change	Climate change is high on the political agenda
	A vast majority believes that the use of fossil fuels and non-renewable materials must be stopped as soon as possible
	Some knowledge among the respondents about how forests store carbon
	FBB and WMBs are seen by the majority as a less harmful alternatives that could lower the dependency on fossil fuels
	Construction sector is increasingly affected by climate change mitigation policies
Economy	FBB is seen as beneficial for the economy by increasing the economic self-sufficiency in Sweden and generating more jobs on the countryside
	WMBs are seen as faster and cheaper to build than steel and concrete buildings
Housing	Strong tradition of building with wood in Sweden
	Pressing need for new housing in Sweden
	Industry collaborations and government incentives aiming at promoting wood as a construction material
	WMBs are seen as healthier than concrete buildings
General attitudes	Generally a positive attitude towards WMBs and FBB Familiarity with the concepts generally result in a more positive attitude
	A majority of the respondents think that the risks related to FBB are not greater than its benefits

Table 12 indicates that there are several areas in which enabling factors can be found, including climate change, economy, housing and general attitudes.

According to Geels *et al*. (2016), LCTs are substantial changes in the systems that serve society so that these systems have less impact on the climate. Geels *et al*. (2016) also state that the SA of low-carbon options can be assessed by analysing the interpretations of different social groups. Furthermore, the ST-transition theory provides information about how different actors influence the implementation of these low carbon options. This study indicates that the SA in the form of both socio-political and market acceptance introduced by Wüstenhagen *et al*. (2007)

of FBB and WMBs can be seen as enabling factors for implementing the LCT of FBB in the housing system in Sweden. The majority of the respondents were positive towards these concepts, even though they were not always familiar with it.

Climate change is also high on the political agenda in Sweden (Government Offices of Sweden 2017; Swedish Environmental Protection Agency 2018). As the majority of the respondents claimed that they were familiar with how forests store carbon, it seems like the majority of the respondents understand why FBB and WMBs can be seen as a low carbon option. The majority of the respondents also claimed that FBB and WMBs were seen as less harmful alternatives that could lower the Swedish dependency on fossil fuels, regardless of their knowledge of the meaning of the concepts. These views are in line with how policymakers (Hemström *et al*. 2012; Government Offices of Sweden 2018a; b; c; Swedish Environmental Protection Agency 2019) and scientists perceive FBB and WMB (Erlandsson *et al*. 2018).

Another enabling factor is respondents regarding FBB and WMBs as positive because they can offer economic benefits to the Swedish economy, construction projects and individuals. Geels (2002) state that ST-systems are resistant to change because of the interdependence of elements and the rules which determine practices and ways of thinking in the ST-regime. However, if WMBs are widely perceived as being faster and cheaper to build, the set of rules within the ST-regime might become questioned, especially since there is a pressing need for new and affordable housing in Sweden (National Board of Housing, Building and Planning 2018b). A faster and cheaper building process helps constructors to more efficiently perform their practices, i.e. building houses rapidly and cheaply. Faster and cheaper processes might create incentives for constructors to consume wood instead of concrete to reach the high construction targets suggested by Boverket.

The industry collaborations and government incentives aimed at promoting wood as a construction material suggested by Hemström *et al*. (2011) among others (Government Offices of Sweden 2018a; Svenska Skogen 2019; Svenskt Trä 2019; Svenskt Träbyggnadskansli 2019) are examples of dynamics of the MLP. These dynamics have, according to Geels (2011), the potential to break up the ST-regime and are hence seen as enabling factors in this study. The industry collaborations work from the niche level by creating dominant designs of WMB and financing information campaigns to promote wood. From the ST-landscape, the government tries to promote wood as a construction material through strategies and collaboration programmes together with the collaboration partners such as the Nordic countries. Hence, the pressure is put on the ST-regime both from above and below.

6.3.2 Hindering factors

This study also identifies several hindering factors connected to SA for establishing FBB in the form of WMB in the ST-regime. The most crucial hindering factor is the resistance to change in the ST-system of housing, as suggested by Geels (2002). There are several reasons why ST-systems are change-resistant. Firstly, the elements of an ST-system are interdependent but tightly connected (Geels *et al*. 2017). For over a century, concrete constructions have been the dominating technique due to legislations hindering wooden constructions in multi-story buildings. During this period, construction techniques, collaborations between actors within the regime as well as rules and beliefs of what can and cannot be done have had the opportunity to solidify (Hemström *et al*., 2012; Mahapatra & Gustavsson, 2008; Bengtson, 2003). As suggested by Roos *et al*. (2010), this has resulted in important decision-makers in the building process, such as structural engineers and architects, being affected by normative beliefs about wood. They, therefore, prefer concrete as a construction material. Radical innovations such as

WMBs are, therefore, difficult to establish on the market as the elements of the multi-story buildings industry are structured to favour concrete as the primary building material.

ST-systems also change slowly because of economic reasons and the fact that artefacts and material networks contain a certain hardness, which makes them challenging to change. It might be unfavourable to invest in new technology. Also, companies might have created economies of scale with their know-how of the dominant technology. Moreover, material structures such as buildings inhibit a particular harness and are not easily changed (Geels 2004). Houses inhibit this material hardness. The long lifecycle and capital-intensive establishment of buildings create few opportunities for end consumers to actively choose to live in a WMB before a steel and concrete building. Only 10% of the newly built multi-story buildings that are built every year are WMBs (Statistics Sweden 2019b; SWFI 2019). According to Spaargaren (2003), who applied practice theory to consumer behaviour, production and consumption are linked together. The power of the consumer to change the ST-regime can, therefore, be questioned, as consumers can only consume and have a user opinion of what producers offer. The above-mentioned hindering factors are presented in Table 13 below, along with other hindering factors found in this study.

Table 13. Hindering factors for establishing forest-based bioeconomy in the socio-technical regime of the housing system in Sweden

Area	Hindering factor
ST-regime	Strong interconnectedness of the elements in the ST-regime
	Few possibilities for consumers to actively choose to live in a WMB
	Incremental innovation to lessen the climate impact of concrete which can become a competing alternative to WMBs
General attitude	Vast majority of the respondents doesn't know what FBB is
	Generally, the respondents that are not familiar with FBB are less positive towards FBB
	A large part of the respondents does not regard WMBs as having any benefits compared to steel and concrete buildings
	Risks with FBB are perceived as they need to be fully understood before implementing
Properties of WMBs	Perceived higher risk of fire in WMBs
	Few incentives for sceptic respondents to actively choose to live in a WMB rather than in another building
	Offers the same function to end consumers
Housing	Need of knowledge and resources within the industry to meet building needs
Raw-material access	Forests as a resource is limited

As indicated in Table 13, there are more areas where hindering factors can be found then only the ST-regime. Another area is the general attitude towards FBB and WMBs. The majority of the respondents did not know about FBB, and these were generally more sceptic towards FBB. This was also true for WMBs as a large part of the respondents did not believe that WMBs offer benefits compared to steel and concrete buildings. That WMBs are not perceived as offering benefits compared to steel and concrete buildings can be seen as a hindering factor, as there then might be few incentives for these consumers to actively choose to live in a WMB rather than in another option. Practice theory suggests that consumption is the result of practices that are performed (Warde 2005; McMeekin & Southerton 2012). This implies that for consumers, it is not the housing itself that is important but what practices the housing helps the consumer to perform. With this view, implications for consumers to choose WMBs before other alternatives become even smaller, as the main difference between WMBs and steel and concrete buildings are the construction material, rather than the function of the building. Unless the function of climate change mitigation is essential for the consumer, there are seemingly few

functions that differ between the buildings, which is a dilemma for low carbon options according to Geels *et al*. (2017).

An important hindering factor is that the majority of the respondents, regardless whether they were familiar with WMBs or not, agreed to the statement that WMBs have a higher risk of fire than steel and concrete buildings. This perception is also found within the industry, as the fire properties of wood as a construction material are heavily debated and might result in more expensive insurances for WMBs than concrete buildings (Swedish Association of Local Authorities and Regions 2013; Höghus av trä- Brandskyddsföreningen, Almedalen 2015 - YouTube 2015). However, some studies indicate the opposite (Eriksson *et al*. 2016) suggesting that the beliefs and cognitive rules that Geels (2011) describes, determine the actions within the sub-regimes of the ST-regime of what is a hindering factor in terms of fire properties of wood.

Even though radical innovations do not happen within the ST-regime, incremental innovation does (Geels, 2011). Within the ST-regime of multi-story buildings, incremental innovation to lessen the climate impact of concrete is taking place (Nielsen & Glavind 2007; Erlandsson *et al*. 2018). This could potentially also be a hindering factor, as the advantages of WMB in terms of climate impact might become fewer. As the majority of the actors within the ST-regime already prefers concrete before wood, a green concrete alternative would likely be chosen before wood.

The population increase and the need for new housing (National Board of Housing, Building and Planning 2018b) might not only be an enabling factor for WMBs, but also a hindering factor as the sector itself has indicated a need for more knowledge and resources to be able to meet the needs (National Board of Housing, Building and Planning 2018b). As practice theory suggests that consumption is the result of practices rather than the practice itself (Warde 2005; McMeekin & Southerton 2012), the urgent need to produce new housing might have a stabilising effect on the ST-regime. This because previously used construction material might more easily help constructors, which can be seen as consumers of construction material, to perform their practices.

Lastly, the forest resource is not infinite, and there is an ongoing discussion in Sweden, whether there are enough forest resources to fulfil all future needs sustainably. The forest resource is suggested to replace fossil-based materials in several areas, and at the same time, there is a need to protect larger areas of forest to maintain biodiversity and the functions of the forest ecosystem (Axdorff 2018; Johansson 2018; Nilsson 2018; Swedish Environmental Protection Agency 2019). Whether WMBs contribute to deforestation and biodiversity loss or not was also judged differently by the respondents as approximately half of them agreed with this statement, while the rest did not. Similar to the energy industry studied by Wüstenhagen *et al*. (2007), SA and a licence to operate are needed for the forest industry along with access to sustainably produced raw material.

The coming chapter chapters discuss the findings in this analysis in relation to other studies and the development in society.

7 Discussion

In this section the findings of the analysis are discussed in relation to other studied and the development in society.

7.1 Socio-political acceptance of forest-based bioeconomy

In this study, the socio-political acceptance of FBB was studied among a group of Swedish citizens. Several scholars have pointed out this field of study as essential to understanding and previously unexplored by research (Toppinen *et al*. 2017; Winkel & European Forest Institute 2017; Mustalahti 2018; Peltomaa 2018). There are a limited number of relevant empirical studies to relate these results with, because of the exploratory nature of this study. However, Hodge *et al*. (2017) studied how several other stakeholder groups perceived the concept of BE and found that BE is a widely accepted concept, which is also indicated by this study. Hodge *et al*. (2017) also found that representatives from all stakeholder groups studied could define bioeconomy, which differs from the results of this study as the majority of the respondents did not know the meaning of FBB.

Even though a large part of the respondents was positive towards FBB, some were not. FBB can be seen as a set of practices that differ from the practices in the dominant ST-regime. According to McMeeking & Southerton (2012), different social groups engage in and understand practices differently, which explains why the respondents perceived the concept differently. Similarly, Hodge *et al*. (2017) found that different stakeholder groups perceived FBB differently. However, climate change was the most significant positive aspect connected to FBB found in this study and by Hodge *et al*. 2017.

Hodge *et al*. 2017 also conclude that the industry sees opportunities for new markets in the BE, which is in line with this study, as the majority of the respondents believed that BE would generate more jobs especially in rural areas where the forest industry often is placed. If this is possible in reality remains unclear, as some stakeholders interpret BE as 'business as usual' (Hodge *et al*. 2017b). This could, in a future discourse, hurt the BE's primary objective to phase out the fossil fuels and non-renewable resources. Hodge *et al*. 2017 also conclude that hindering factors for implementing BE were little knowledge about the forest resource and that forest is a finite resource if not managed properly. This lies in line with the findings of this study as the secondary data indicates that there is an ongoing discussion about the access to forest resources in Sweden (Axdorff 2018; Johansson 2018; Nilsson 2018; Swedish Environmental Protection Agency 2019).

In Sweden, there is no official BE strategy, solely one publication on how the concept of BE should be interpreted, see (FORMAS, 2012). An official BE strategy could play an important role when implementing BE and broaden the discourse to "regular" citizens. Examples of strategies can be seen all over the world and an example that concern Sweden is the strategy in the EU and the Nordic minister council. Mustalahti (2018, pp. 3785–3786) states that "...once the active debate is missing, there may not be enough information or capacity to enable and empower citizens to enter into a constructive debate, apart from the values or emotions held by individual citizens". This study also confirms the picture Mustalahti (2018) gives in her article; that regular people have limited knowledge about FBB and need to be involved in the discourse in today's society. The people included in this study need more knowledge about FBB to be a part of the debate and the discourse about FBB.

7.2 Market acceptance of wooden multi-story buildings

The analysis indicates that a small majority was familiar with WMBs and that the respondents were in general positive towards WMBs. The respondents of this study were most positive regarding the lower climate impact of WMBs compared to steel and concrete buildings. As few previous studies have been made on the market acceptance of WMBs, there are few possibilities to compare the findings of this study to similar studies. However, the WBCSD (2008) found similar results as they investigated consumer attitudes and behaviours towards sustainable consumption. They found that consumers are increasingly aware and concerned about sustainability issues and that the attitude towards sustainable consumption has become more positive (World Business Council for Sustainable Development 2008).

Despite this, the WBCSD (2008) also found that there is a gap between consumer attitudes and their actual behaviour, which means that even though consumers have a positive attitude and say they want to consume more sustainably, they do not necessarily act according to their beliefs. Several barriers were found to behaviour change of which a) lack of knowledge or understanding of a problem; b) unwillingness to compromise quality; c) price and; d) convenience were the most important. However, if environmentally responsible options offered additional benefits to the individual consumer, such as a lower price or convenience, the consumers were more inclined to consume sustainably (World Business Council for Sustainable Development, 2008). Smiliarily Geels (2011) states that sustainable or low carbon products are at a disadvantage in comparison to mainstream products, as they often do not offer the consumer any apparent benefits in terms of quality and price. Solely they offer less damage to the climate or some other environmental aspect, which is a public good. The incentives for the individual to buy more sustainable or low carbon products is, therefore, limited. However, the findings of this study suggest that a majority of the respondents perceive houses built in wood as healthier and faster and cheaper to build than steel and concrete ones. This implies a perceived higher living standard and a lower purchasing and living cost for the end consumer who buys or rents an apartment in a WMB. WMBs then offers perceived benefits not only to the climate but also to the end consumer in the form of lower living costs and a healthier living environment.

In contrast, a study by Mark-Herbert *et al*. (2019) indicates that residents in WMBs choose their housing based on location, size, price and atmosphere of the apartment, rather than the environmental properties of the apartment. This implies that even though the respondents of this study were positive towards WMBs, they might not necessarily choose to live in one unless it offers some obvious benefits. However, it also implies that people with negative attitudes towards FBB and WMB might still live in a WMB, as the environmental properties of housing are not of primary interest for most people when choosing where to live.

To put more focus on the function of the housing rather than its properties could perhaps attract more interest for WMBs among presumptive residents (Zhao *et al*. 2015). However, one building property that is of high importance for WMBs is fire resistance, as the majority of the respondents in this study see WMBs as less fire-resistant than concrete and steel buildings. As one of the essential hindering factors to consume sustainably found in the report by WBCSD (2008) was a lack of knowledge and understanding, a transition towards FBB in the multi-story buildings sector in Sweden could potentially benefit from spreading more information about WMBs. In particular, the benefits with WMBs and their fire properties. This is already done through industry collaborations and government incentives to increase the usage of wood in construction in Sweden (Hemström *et al*. 2011; Government Offices of Sweden 2018a; Svenska Skogen 2019; Svenskt Trä 2019; Svenskt Träbyggnadskansli 2019). However, these initiatives

mainly address professionals rather than the public, although one campaign named the Swedish Forest targets consumers directly.

7.3 Enabling and hindering factors connected to social acceptance of forest based bioeconomy and wooden multi-story buildings

One of the enabling factors that were found in this study was the strong tradition of building in wood that exists in Sweden, as 90% of single-family houses are built in wood (Hemström *et al*. 2012). This tradition indicates that when the individual has a choice of building material, wood tends to be the first option. However, when multi-story buildings are built only 10% of the buildings are built in wood (Statistics Sweden 2019b). Multi-story buildings are most often built by companies which apply a product dominant logic, focusing on the product rather than co-creation together with the consumer to get to know what the consumer wants. It can, therefore, be assumed that if a service-dominant logic as suggested by Vargo & Lusch (2004) were applied in the multi-story buildings sector, more houses would be built in wood, as the end consumer seems to favour wood as a construction material rather than concrete.

Even though the WBCSD (2008) suggests that the difference between consumer attitudes and actual behaviours might be a hindering factor for implementing low-carbon innovations, other scholars like Bourdeau (1999) and Belz & Peattie (2012) are more favourable. Bourdeau (1999) and Belz & Peattie (2012) claim that private actors can turn sustainability into an advantage and that low-carbon innovation can be both sustainable and commercially viable. An example is the need for new housing (National Board of Housing, Building and Planning 2018b), which can be seen as an opportunity for WMBs, as these buildings not only have a lower climate impact (Perez-Garcia *et al*. 2005; Dodoo *et al*. 2012; Gong *et al*. 2012; Nässén *et al*. 2012; IEA 2018) but are also generally fast to build (Swedish Association of Local Authorities and Regions 2013). The WMBs-industry could, therefore, potentially benefit from applying a service-dominant logic not only in terms of the end-consumer but also with decision-makers in mind. With a practice theory approach (Warde 2005; McMeekin & Southerton 2012), an FBB would be easier to implement as WMBs could potentially help decision-makers perform their practices by offering apparent advantages such as shorter construction time, lower cost or other needs that are held by decision-makers.

Another aspect worth discussing is the power of the end consumer in the building process. Even though several authors highlight the importance of the end consumer in low-carbon transitions (Toppinen *et al*. 2017; Winkel & European Forest Institute 2017; Mustalahti 2018; Peltomaa 2018), their possibilities to influence the multi-story buildings market is questionable. The main reason is the strong path dependency within the ST-regime of multi-story buildings in Sweden. According to Geels (2011), ST-transitions take place when an internal momentum is built up in the niche and external pressures from the ST-landscape is put on the ST-regime. For the multi-story buildings sector, the transition process seems rather slow as the ban of WMBs was lifted 25 years ago (Hemström *et al*. 2012) and government incentives (Government Offices of Sweden 2018a) as well as other factors in the ST-landscape such as climate change (Intergovernmental Panel on Climate Change 2018) create external pressure on the ST-regime. Also, the internal momentum in the niche has developed so that there are a dominant design and even collaborations within the WMBs-sector to promote these buildings (Svenska Skogen, 2019; Svenskt Trä, 2019; Svenskt Träbyggnadskansli, 2019).

One explanation for this slow transition can be that housing is a capital-intensive investment for both builders and owners. Housing is not often bought in a market, compared to consumables. Similarily Geels (2004) states that hardness in artefacts and economic considerations are some of the reasons why ST-systems are resistant to change. Hemström *et al*. (2017) suggest that the influence of contract managers in the multi-story buildings sector is probably one of the most important reasons why the path dependency of the ST-regime is maintained. This indicates that widely held beliefs in the ST-regime are the reason why FBB and WMBs are challenging to implement in the housing system in Sweden. This is also supported by Bengtson, (2003), Roos *et al*. (2010) and Hemström *et al*. (2011).

Another reason why low carbon options such as FBB and WMBs have not been widely implemented in the multi-story buildings sector in Sweden is suggested by Moberg *et al*. (2019). According to Moberg *et al*. (2019, p. 505), the governing strategy connected to climate change mitigation in the housing system in Sweden places the responsibility for mitigation actions in the individual citizen, rather than other actors. As this study has indicated that the power of the consumer in the building process of multi-story buildings is limit edit might be one reason why FBB and WMB have not been widely implemented yet.

In the next chapter, the main findings of this study are summarised, and a conclusion is presented.

8 Conclusions

This chapter presents the conclusions of the thesis, enabling factors for establishing WMBs in the ST-regime of multi-story buildings in Sweden, reflections on choices made with regards to method and theory and suggestions for future studies.

8.1 Contributions to the field of understanding low carbon transitions

At the beginning of this study, two problems were identified; that LCTs need SA to be implemented (Ockwell *et al*. 2009; Geels *et al*. 2017) and that innovations often fail to be established in the marketplace, primarily because of consumers resistance to change (Heidenreich & Spieth 2013). The innovation of WMBs is established in the marketplace in Sweden to some extent (Statistics Sweden 2019b), even though it has not yet been established in the ST-regime (Hemström *et al*. 2017). However, this study indicates that there is market acceptance of WMBs, is not well established and understood. This suggests that regarding WMBs it is not the end consumers resistance to change that is the primary reason why WMBs are not more widely adopted in the market today, but rather the path dependency and strong interconnectedness within the ST-regime as suggested by previous studies (Bengtson 2003; Roos *et al*. 2010; Hemström *et al*. 2011, 2012, 2017).

Regarding the socio-political acceptance of FBB, which is needed to implement LCTs as these transitions are not primarily driven by private economic benefits as historical transitions (Geels *et al*. 2017), this study indicates that there is some acceptance, but limited knowledge of the concept. The understanding of FBB is hence lower for citizens and consumers compared to the stakeholder groups studied by Hodge *et al*. (2017). The limited understanding of FBB can, therefore, be a hindering factor for implementing FBB in the housing system in Sweden as well as more widely in the Swedish economy, as public policy is needed to create economic frame conditions that support LCT according to Geels *et al*. (2017). Ockwell *et al*. (2009) state, however, that governments tend to be reluctant to implement such low carbon policies to avoid bad public opinion figures. The key to success for implementing low carbon policies is, according to Giddens (2009) to gain widespread political support. However, if the public does not understand the concept of FBB, widespread political support might be a challenge to get. On the other hand, this study indicates that the respondents were in general positive towards the concepts of both FBB and WMB even though they were not entirely familiar with them.

8.2 Enabling factors

This study aimed to identify enabling and hindering factors connected to SA of an LCT in Sweden. The enabling and hindering factors for establishing WMBs in the ST-regime of multi-story buildings in Sweden today found in this study are explained in Figure 11 below.

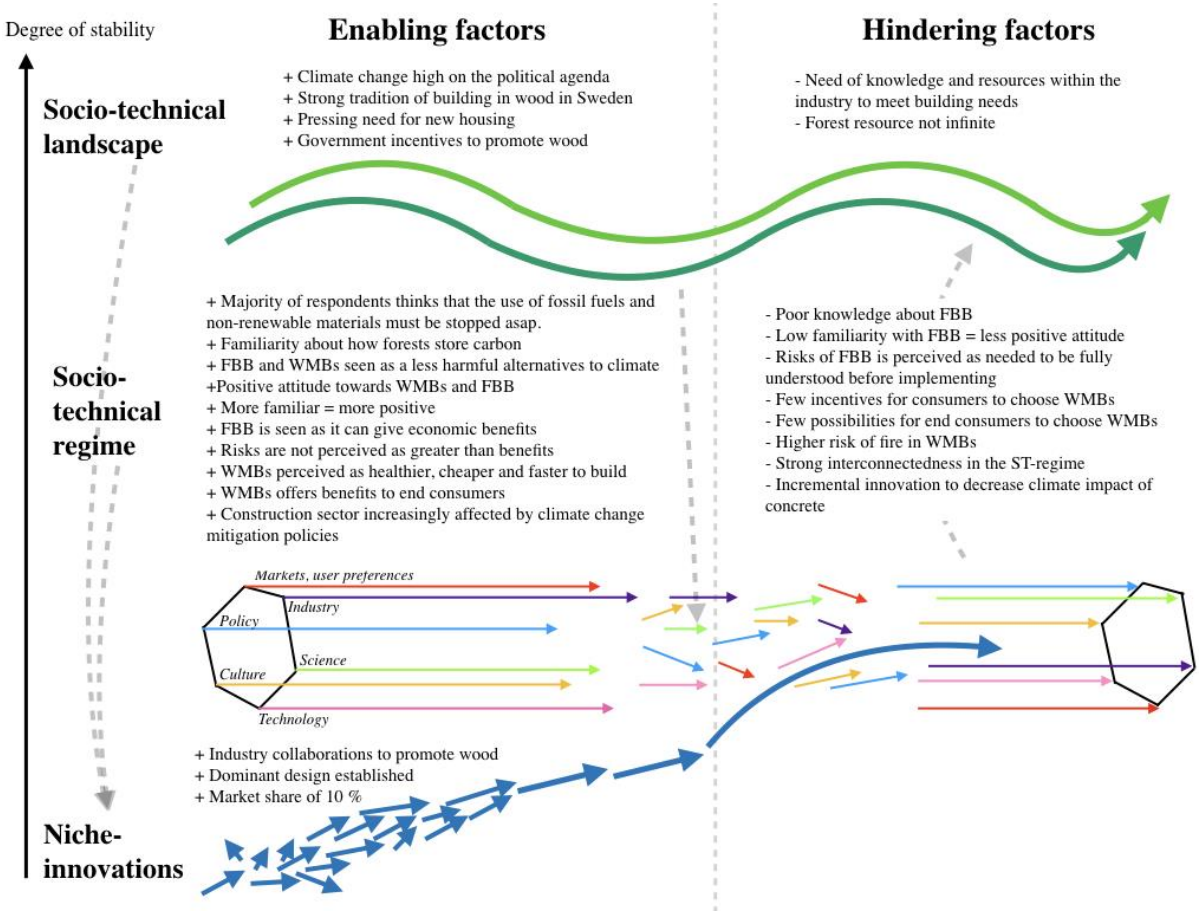

Figure 14. The enabling and hindering factors for establishing wooden multi-story buildings in the socio-technical regime of multi-story buildings in Sweden. Adapted from Geels (2018, p. 226).

Figure 15 shows the enabling and hindering factors identified in this study. The factors have been placed in the MLP, based on what dimension of the MLP they belonged. Essential hindering factors are the strong ST-regime within the multi-story buildings sector in Sweden and the poor knowledge about FBB among the respondents. Two other critical hindering factors are that there are few incentives and opportunities for consumers to choose WMBs. Moreover, the limited forest resource is also seen as a crucial hindering factor. There are also several critical enabling factors, as can be seen in Figure 15. The pressure is put on the ST-regime both from above and below. From above in the form of government policies and strategies in the ST-landscape. From below in the form of industry collaborations and dominant designs on the niche level. Moreover, the public acceptance of WMBs seems to be relatively high as they can offer benefits not only to the climate but also to individuals.

As the study was only exploratory and used convenience sampling, no general conclusions about the whole Swedish population can be drawn. However, this study suggests that there might be room for creating even more positive attitudes and knowledge about WMBs in consumers.

8.3 Reflection on choices

A significant limitation in the choice of method of this study is the sampling method. In this study convenience sampling was used, which limits the possibilities to generalise the findings in this study. This study should be seen as an explorative pilot study, which can give implications for future research.

There is also a risk of an interviewer effect in the survey answers, primarily because the respondents were given incentives to answer the survey and because the respondents had personal contact with the survey personnel. The personal contact might have urged the respondents to answer the survey pleasingly and, therefore, the answers are biased. The respondents also answered the survey in a public environment, which might make the respondents more stressed and eager to be done and less thoughtful.

Moreover, this study is exploratory, which is why the choice of method might have been inappropriate. This study uses a quantitative approach, and this approach is often used to confirm something that is already known. However, this study aims at identifying something that is not previously known, which is the main reason why a qualitative approach could have served better, as a qualitative approach can be more exploratory, giving the researcher opportunities to ask attendant questions.

According to Geels *et al*. (2016), the ST-transition theory can be used to:

"... assess the socio-political feasibility and social acceptance and legitimacy of various low-carbon options, by analysing the interpretations, strategies and resources of different social groups" (Geels *et al*., 2016, p. 580).

Even though Geels *et al*. (2016) claim that ST-transition theory can be used to assess the socio-political feasibility and SA of LCTs, the MLP on ST-transitions offers little guidance on how to define and evaluate these factors. The main focus of the MLP are the structures surrounding the producers and the products, as well as political governance, leaving out several of the groups which are included in the model of SA developed by Wüstenhagen *et al*., (2007). To fully assess the socio-political feasibility and SA, the MLP on ST-transitions would benefit from being further developed with definitions of SA as well as how it can be measured and interpreted. As mentioned in the introduction, SA is of high importance for implementing LCTs in society and therefore, there is a need to consider these aspects more thoroughly in the future.

Another critique against the MLP on ST-transitions is the high level of flexibility when applying it and the influence of the analyst, which might cause bias (Genus & Coles, 2008). One way to handle this is through triangulation of data, methods and theories (Robson & McCartan, 2016), which has been applied in this study. In this study, both primary and secondary empirics is used in the form of survey responses and desktop research. Moreover, the MLP on ST-transitions has been complemented with practice theory and the model of SA of low carbon innovations. However, there is still a risk of an author's bias, as in all other research.

8.4 Suggestions for future research

This study provides a foundation for future studies aimed at comparing the development of public perceptions of FBB and WMBs. This study can be seen as a point zero measure, which future studies can build on. Moreover, public acceptance of FBB and WMBs could also be studied with a more qualitative approach, generating more in-depth information about people's perceptions and how these affect an LCT. Other suggestions would be to study which building material and properties of housing that people prefer and how they rate different factors of FBB and WMBs, e.g. biodiversity over carbon storage etcetera.

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Personal messages

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Appendicies

Appendix I.

The English version of survey that was distributed to the respondents

UNDERSTANDING URBAN CITIZENS' PERCEPTIONS OF THE BIOECONOMY *This questionnaire is by a European-wide research network on Bioeconomy: PerForm – Perceiving the Forest-based Sector in the Bioeconomy (www.perform-bioeconomy.info). The project is funded by the European Forest Institute (www.efi.int) and facilitated through network member organisations in Austria/BOKU, Finland/Univ. Helsinki, France/IRSTEA, Germany/Univ. Freiburg, Italy/Univ. Padova, Russia/Univ. Saint Petersburg, Slovakia/Tech. Univ. Zvolen and Sweden/SLU.*		Strongly disagree	Disagree	Mildly disagree	Mildly agree	Agree	Strongly agree
My opinion of multi-storey building with a mostly wooden frame in [COUNTRY] [Choose what best corresponds your opinion]							
1	I am familiar with wooden multi-storey buildings	1	2	3	4	5	6
2	Are faster and cheaper to build than steel or concrete ones	1	2	3	4	5	6
3	Do not last as long as steel or concrete buildings	1	2	3	4	5	6
4	Need more repairs and maintenance than steel or concrete buildings	1	2	3	4	5	6
5	Need less insulation than steel or concrete buildings	1	2	3	4	5	6
6	Are healthier to live in than steel or concrete buildings	1	2	3	4	5	6
7	Have a higher risk of fire than steel or concrete buildings	1	2	3	4	5	6
8	Are less harmful to climate than steel or concrete buildings	1	2	3	4	5	6
9	Do contribute to global deforestation and biodiversity loss	1	2	3	4	5	6
10	Do generate income and well-being to more people than steel or concrete buildings	1	2	3	4	5	6
My opinion of storing carbon in forests in [COUNTRY]							
11	I am familiar with how forests store carbon	1	2	3	4	5	6
12	Managed forests have great potential to reduce carbon emissions	1	2	3	4	5	6
13	How forests are being managed can threaten carbon stocks in forests	1	2	3	4	5	6
14	Land/forest owners need support to maintain and manage forests	1	2	3	4	5	6
15	Land/forest owners must be compensated monetarily for storing carbon in forests	1	2	3	4	5	6
My opinion of forest-based bioeconomy in [COUNTRY]							
16	I know the meaning of forest-based bioeconomy	1	2	3	4	5	6
17	Forest-based bioeconomy decreases our dependency on oil and fossil fuels	1	2	3	4	5	6
18	Forest-based bioeconomy increases our economic self-sufficiency	1	2	3	4	5	6
19	Forest-based bioeconomy generates new jobs and well-being in rural areas	1	2	3	4	5	6
20	Forest-based bioeconomy mainly benefits large companies and their shareholders	1	2	3	4	5	6
21	Forest-based bioeconomy products should be of domestic origin to be more sustainable	1	2	3	4	5	6
22	Agriculture-based bioeconomy is more important for society than forest-based bioeconomy	1	2	3	4	5	6
23	The risks of forest-based bioeconomy are greater than its benefits	1	2	3	4	5	6
24	The risks of forest-based bioeconomy must be understood before we fully embark on it	1	2	3	4	5	6
25	All different views must be seriously considered when forest-based bioeconomy develops	1	2	3	4	5	6
26	Use of fossil fuels and non-renewable materials must be reduced as soon as possible	1	2	3	4	5	6
27	Environmental regulation limits overall economic development and growth	1	2	3	4	5	6
28	Humans will be able to solve environmental problems when technology develops	1	2	3	4	5	6
29	Despite our special abilities, humans are still subject to laws of nature	1	2	3	4	5	6
30	Humans have the right to modify the natural environment to suit their needs	1	2	3	4	5	6
31	The balance of nature is very delicate and easily upset	1	2	3	4	5	6
32	I trust information on forest-based bioeconomy from government officials	1	2	3	4	5	6
33	I trust information on forest-based bioeconomy from researchers and experts	1	2	3	4	5	6
34	I trust information on forest-based bioeconomy from environmental and civic organizations	1	2	3	4	5	6
Respondent background information							
35	Age						
36	Gender	Female		Male		Other	
37	Do you own more than one hectare of land or forest?	No			Yes		
38	Which of the following best suits your current area of residence?	Urban		Suburb		Rural	
Data collected through this survey will be treated confidentially and anonymously for the purposes of the PerForm project, in compliance with the General Data Protection Regulation (GDPR), Regulation (EU) 2016/679. By filling the questionnaire you give PerForm network staff the permission to process data you provide for the purposes of the PerForm project.							
To be completed by the surveyor							
Who collected:	*Where collected:*	*When collected:*					

The Swedish version of the survey that was distributed to the respondents:

SVENSKA KONSUMENTERS SYN PÅ SKOGSBASERAD BIOEKONOMI *Denna enkät är en delstudie inom det europeiska forskningsprojektet Perform - Perceiving the Forest-based Sector in the Bioeconomy. Projektet utforskar olika perspektiv på bioekonomi och i denna enkät vill vi undersöka svenska konsumenters syn på en skogsbaserad bioekonomi. Perform finansieras av det europeiska skogsinstitutet EFI (www.efi.int) och är ett samarbete mellan Österrike/BOKU, Finland/Univ. Helsinki, Frankrike/IRSTEA, Tyskland/Univ. Freiburg, Italien/Univ. Padova, Ryssland/Univ. Saint Petersburg, Slovakien/Tech. Univ. Zvolen och Sverige/SLU. (www.perform-bioeconomy.info*		Jag håller verkligen inte med	Jag håller inte med	Jag håller delvis inte med	Jag håller delvis med	Jag håller med	Jag håller verkligen med
Min åsikt om flervåningshus med stomme i trä i Sverige [Välj d*et a*lternativ som bäst överensstämmer med din åsikt]							
1	Jag känner till att det finns flervåningshus i trä	1	2	3	4	5	6
2	De går snabbare och är billigare att bygga än hus byggda i stål eller betong	1	2	3	4	5	6
3	De håller inte lika länge som hus byggda i stål eller betong	1	2	3	4	5	6
4	De behöver fler reparationer och mer underhåll än hus byggda i stål eller betong	1	2	3	4	5	6
5	De behöver mindre isolering än hus byggda i stål eller betong	1	2	3	4	5	6
6	De är mer hälsosamma att bo i än hus byggda av stål eller betong	1	2	3	4	5	6
7	De medför större brandrisk än hus byggda i stål eller betong	1	2	3	4	5	6
8	De är mindre skadliga för klimatet jämfört med hus byggda i stål eller betong	1	2	3	4	5	6
9	De bidrar till global avskogning och förlust av biodiversitet	1	2	3	4	5	6
10	De genererar inkomst och välmående till fler människor jämfört med hus byggda i stål eller betong	1	2	3	4	5	6
Min bild av inlagring av koldioxid i den svenska skogen							
11	Jag känner till hur skogar binder koldioxid	1	2	3	4	5	6
12	Brukade skogar har stor potential att minska koldioxidutsläpp	1	2	3	4	5	6
13	Hur skogen brukas kan hota inlagringen av koldioxid i skogen	1	2	3	4	5	6
14	Markägare behöver stöd för att förvalta och bruka sina skogar	1	2	3	4	5	6
15	Markägare måste bli ekonomiskt kompenserade för att de binder koldioxid i sin skog	1	2	3	4	5	6
Min åsikt om skogsbaserad bioekonomi i Sverige							
16	Jag förstår betydelsen av skogsbaserad bioekonomi	1	2	3	4	5	6
17	Skogsbaserad bioekonomi minskar vårt beroende av olja och fossila bränslen	1	2	3	4	5	6
18	Skogsbaserad bioekonomi ökar vår ekonomiska självförsörjning	1	2	3	4	5	6
19	Skogsbaserad bioekonomi genererar nya jobb och en välmående landsbygd	1	2	3	4	5	6
20	Skogsbaserad bioekonomi gagnar främst stora företag och dess aktieägare	1	2	3	4	5	6
21	Den skogsbaserade bioekonomins produkter bör ha sitt ursprung i Sverige för att vara hållbara	1	2	3	4	5	6
22	Jordbruksbaserad bioekonomi är viktigare för samhället än skogsbaserad bioekonomi	1	2	3	4	5	6
23	Riskerna med skogsbaserad bioekonomi är större än fördelarna	1	2	3	4	5	6
24	Vi behöver förstå riskerna med skogsbaserad bioekonomi till fullo innan vi utvecklar den fullskaligt	1	2	3	4	5	6
25	Alla olika synsätt måste tas på allvar när skogsbaserad bioekonomi utvecklas	1	2	3	4	5	6
26	Användandet av fossila bränslen och icke-förnybara material måste upphöra så fort som möjligt	1	2	3	4	5	6
27	Miljölagstiftning begränsar den övergripande ekonomiska utvecklingen och tillväxten	1	2	3	4	5	6
28	Människan kommer kunna lösa miljöproblem genom teknologisk utveckling	1	2	3	4	5	6
29	Trots våra speciella förmågor måste människan anpassa sig till naturens lagar	1	2	3	4	5	6
30	Människan har rätt att modifiera den naturliga miljön så den passar våra behov	1	2	3	4	5	6
31	Balansen i naturen är väldigt känslig och lätt att rubba	1	2	3	4	5	6
32	Jag litar på information från myndighetspersoner angående skogsbaserad bioekonomi	1	2	3	4	5	6
33	Jag litar på information från forskare och experter angående skogsbaserad bioekonomi	1	2	3	4	5	6
34	Jag litar på information från miljöorganisationer och civilsamhället angående skogsbaserad bioekonomi	1	2	3	4	5	6
Respondentens bakgrundsinformation							
35	Ålder						
36	Kön	Kvinna		Man		Annat	
37	Äger du mer än en hektar (10 000m^2) mark eller skog?	Nej			Ja		
38	Vilket av följande alternativ beskriver bäst ditt område där du bor?	Stad		Förort		Landsbygd	
Data som insamlas genom denna enkät kommer användas inom projektet PerForm och kommer att behandlas konfidentiellt och anonymt enligt dataskyddsförordningen (GDPR), förordning (EU) 2016/679. Genom att fylla i denna enkät godkänner du att forskarna i nätverket använder din data inom ramen för projektet PerForm.							
Ifylls av insamlande forskare							
Inhämtades av:	*Plats:*	*Datum och tidslag:*					

Appendix II.

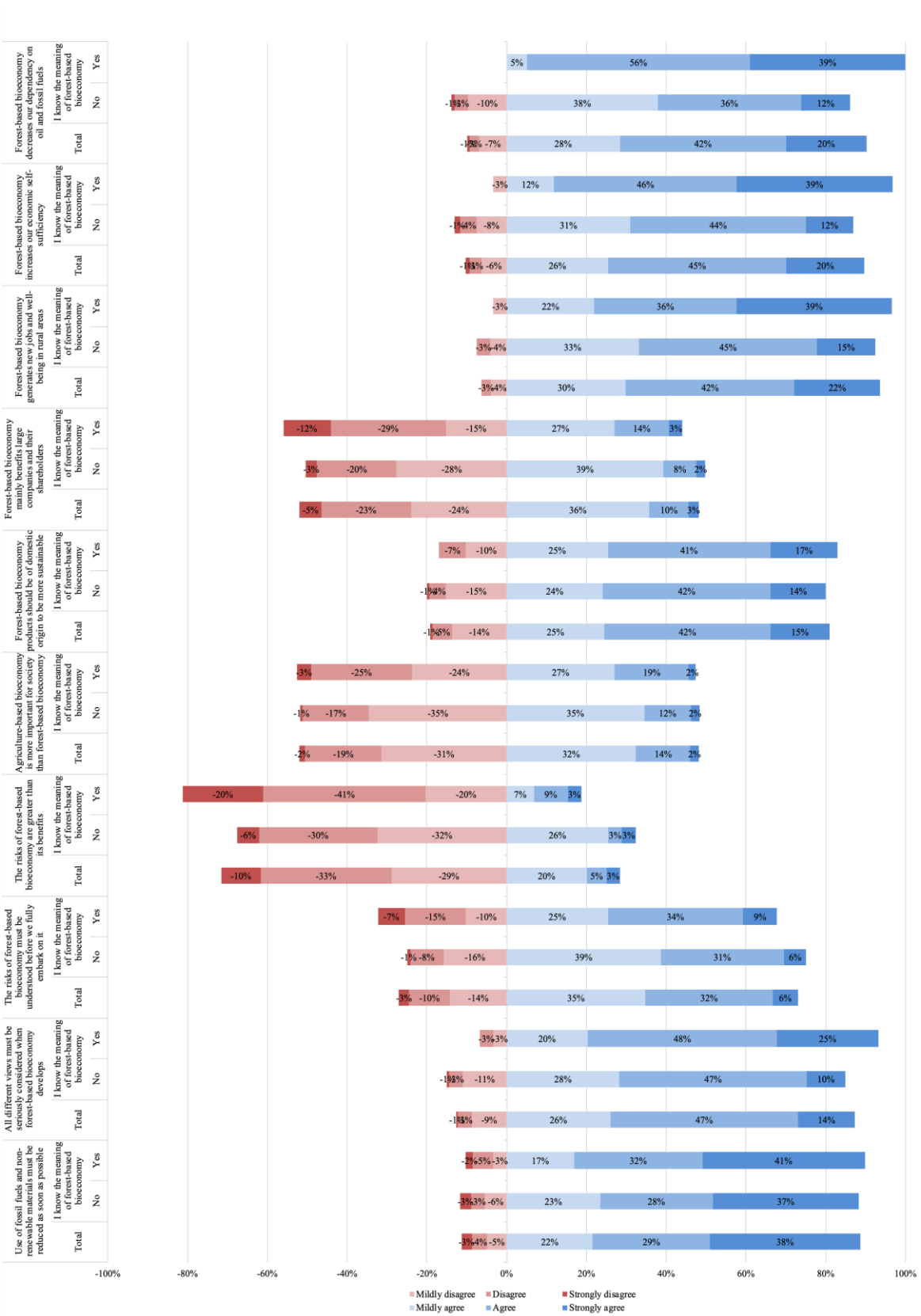

Figure 15. Part I of the frequency distribution bar chart of how the respondents perceived forest-based bioeconomy and wooden multi-storey buildings in total and depending on if they were familiar with the concepts or not.

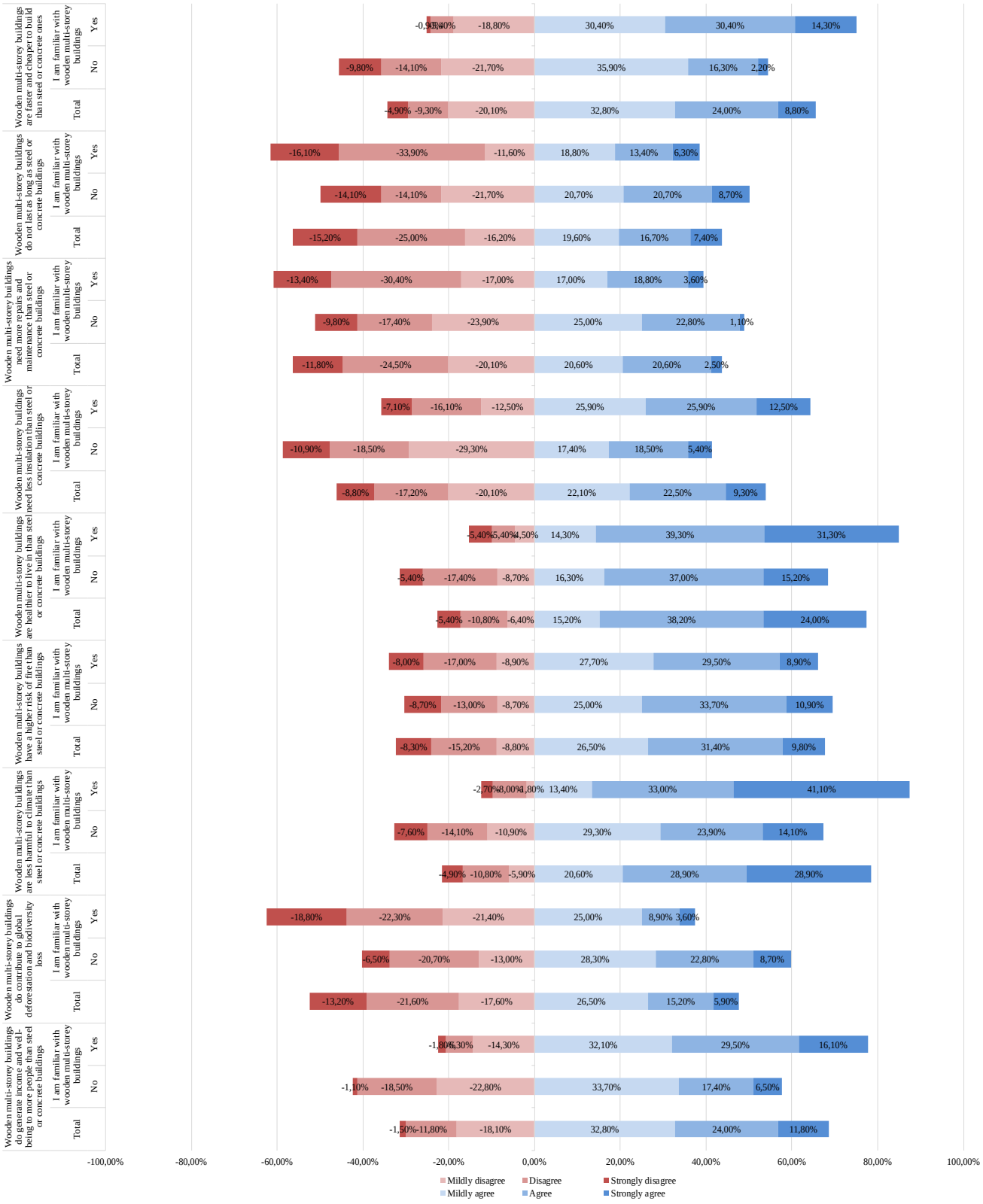

Figure 16. Part II of the frequency distribution bar chart of how the respondents perceived forest-based bioeconomy and wooden multi-storey buildings in total and depending on if they were familiar with the concepts or not.

Appendix III.

Table 14. Overview of definitions of bioeconomy

Country/Organisation (Year)	Definition
(OECD, 2009)	*"...the bioeconomy can be thought of as a world where biotechnology contributes to a significant share of economic output. The emerging bioeconomy is likely to be global and guided by principles of sustainable development and environmental sustainability. A bioeconomy involves three elements: biotechnological knowledge, renewable biomass, and integration across applications"* (OECD, 2009, p 22).
(The White House, 2012)	"*A bioeconomy is one based on the use of research and innovation in the biological sciences to create economic activity and public benefit*" (The White House, 2012, p. 7).
(European Commission, 2012)	"*The bioeconomy encompasses the production of renewable biological resources and their conversion into food, feed, bio-based products and bioenergy. It includes agriculture, forestry, fisheries, food and pulp and paper production, as well as parts of chemical, biotechnological and energy industries. Its sectors have strong innovation potential due to their use of a wide range of sciences (life sciences, agronomy, ecology, food science and social sciences), enabling and industrial technologies (biotechnology, nanotechnology, information and communication technologies (ICT), and engineering), and local and tacit knowledge"* (European Commission, 2012, p. 16)
(European Commission, 2018b)	"*The bioeconomy covers all sectors and systems that rely on biological resources (animals, plants, micro-organisms and derived biomass, including organic waste), their functions and principles. It includes and interlinks: land and marine ecosystems and the services they provide; all primary production sectors that use and produce biological resources (agriculture, forestry, fisheries and aquaculture); and all economic and industrial sectors that use biological resources and processes to produce food, feed, bio-based products, energy and services. (To be successful, the European bioeconomy needs to have sustainability and circularity at its heart. This will drive the renewal of our industries, the modernisation of our primary production systems, the protection of the environment and will enhance biodiversity)*" (European Commission, 2018b, p. 27).
Nordic Minister Council (2018)	"*The bioeconomy encompasses the utilisation of renewable biological resources and the conversion of these resources (including side- and waste streams) into value-added products, technology and services. The products include food, feed, bio-based products, chemicals, materials and bioenergy, while services include, for example, water and air quality, shelter and recreation (e.g. walking, skiing and foraging for berries and mushrooms) and non-anthropogenic outcomes like biodiversity"* (*Nordic Bioeconomy Programme*, 2018, p. 10)

Swedish Research Council for the Environment, Agricultural Sciences and Spatial Planning (FORMAS) (2012)	*"A sustainable production of biomass to enable increased use within a number of different sectors of society. The objective is to reduce climate effects and the use of fossil based raw materials.* *An increased added value for biomass materials, concomitant with a reduction in energy consumption and recovery of nutrients and energy as additional end products. The objective is to optimize the value and contribution of ecosystem services to the economy"* (FORMAS, 2012, p. 9).

Appendix IV.

Table 15. Detailed overview of critique against the multi-level perspective of socio-technical transitions, how it has been responded to and handled in this study

Criticism	Response	How the critique is handled in this study
Lack of agency Smith *et al.* (2005) argue that the MLP does not consider the role of agency (primarily the role of politics) in ST-transitions and that the MLP is too descriptive and structural (Smith *et al.* , 2005, p. 1492). Similar arguments are also presented by Genus & Coles (2008).	According to Geels (2011) *"the MLP is shot through with agency, because the trajectories and multi-level alignments are always enacted by social groups"* (Geels, 2011, p 29). However, Geels (2011) also argues that some types of agency might not be well developed. To handle this political science theories, social movement theories and cultural sociology theories could be implemented in the MLP (Geels, 2011).	As argued by Geels (2011), the MLP is shot through with agency as the elements of the MLP is maintained by different social groups. Because of this agency is inbuilt in the MLP and in this study this critique is disregarded.
Operationalization and specification of regimes Berkhout *et al.* , (2004)and Genus and Cole (2008) state that the distinction between the levels of the MLP is not clearly defined and therefore it is unclear how the MLP should be applied empirically. In particular the ST-regime should be more clearly defined (Genus & Cole, 2008) as it is both being defined as "rules" and "systems" (Markard & Truffer, 2008).	Geels (2011) states that the MLP should have the ability to be applied on different empirical scopes (both whole systems and smaller parts of systems) and that it is up the analyst using the MLP to define the object of analysis. According to Geels (2011), the difference between a system and a regime is that *"System then refers to tangible and measurable elements (such as artefacts, market shares, infrastructure, regulations, consumption patterns, public opinion), whereas regimes refer to intangible and underlying deep structures (such as engineering beliefs, heuristics, rules of thumb, routines, standardized ways of doing things, policy paradigms, visions, promises, social expectations and norms)"* (Geels, 2011, p 31).	The MLP was chosen as a theoretical framework for this study because of its flexibility in scope. While this might be an advantage when looking at a single case study, it obviously have disadvantages if several studies should be compared. However, this study do not aspire to compare different case studies, but instead be more explorative than systematic. How the ST-regime is defined in this study is explained in the coming sections.
Bias towards bottom-up change Berkhout *et al.* (2004) argue that the MLP puts too much focus on the niches as starting point for ST-regime shifts.	By introducing timing and nature of the multi-level interactions to the MLP, Geels and Schot (2007) formulated four transition pathways which suggests that ST-transitions not only happen through bottom-up change, but also through other MLP dynamics.	As this study do not aim at explaining what transition is taking place, this critique is disregarded.
Use of secondary data Many studies that have applied the MLP have been case studies that	This critique is recognized by Geels (2011), who admits that transition case studies have been	This study focuses on a transition that is happening right now. Therefore primary data is much

have made use of secondary data sources. This have been criticized by Genus and Coles (2008) who argues: *"Indeed certain case studies do not set out adequately the research methods governing the collection and analysis of (secondary) data, and rely uncritically on a small number of quite recent accounts of the topic in question, themselves based on secondary data, rather than on documents contemporaneous with the historical period being studied…. If the case studies are constructed poorly or related sources used uncritically then the strength of the MLP as a whole is undermined"* (Genus & Coles, 2008, p 1441).	more illustrative and exploratory than systematic. However, there are also examples of early MLP-studies that have used primary data sources (Geels, 2011). More recent studies have also used primary data (Matschoss & Heiskanen, 2018; Reichenbach & Puhe, 2018).	easier to get hold of than if a historical transition were to be studied. This study is based not only on secondary data but also on primary data from a questionnaire, which is why this critique has been accounted for.
ST-landscape as residual category According to Geels (2011, p 36), the ST-landscape level has been used as a residual category or a "garbage can".	To address this criticism, Geels (2011) suggests that the ST-landscape can be further developed by a) introducing landscape dynamics, b) paying attention not only to elements in the ST-landscape that destabilizes the ST-regime, but also elements which stabilizes it, and c) investigating how shifts in the ST-regime influence the ST-landscape.	In this study the ST-landscape is defined based on the ST-regime and the niche. However, as suggested by Geels (2011), the ST-landscape is further developed by dividing the elements of the ST-landscape as having stabilizing or destabilizing effect on the ST-regime.
Influence of the analyst Genus and Coles (2008) are also critical of the high influence that the analysts choices has on MLP-studies. As an example the analyst choose and interprets: which cases to research, what information should be used and at what level of the MLP, start and end point of the transition, path articulation, among else (Genus & Coles, 2008, p 1442-1443).	This critique has not yet been responded to.	Genus and Coles (2008) are critical of the influence of the analyst when applying the MLP. Primarily because the choices of the analyst create bias. This critique is legitimate for this study. However, Robson and McCartan (2016) state that: *"Issues of bias and rigour are present in all research involving people"* (Robson & McCartan, 2016, p.171). One way to handle the risk of bias is through triangulation of data, observers, methods or theories (Robson & McCartan, 2016). In this study, triangulation of data and methods are applied. The data used is primary data from a questionnaire along with data from other studies and information available from governments and other organisations.
Inability to explain transitions Svensson and Nikoleris (2018)	As a solution, Svensson and Nikoleris (2018) suggest that new	As the aim of this study is to identify enabling and hindering

criticizes the MLP for its inability to explain transitions and how they occur, which is due to the ontological foundations of the MLP. They argue that MLP reduces transitions *"to shifts in the maturity and spread of socio-cognitive rules, without analysis of systemic change"* (Svensson & Nikoleris, 2018, p. 462).	ontological foundations could be applied, such as critical realist foundations.	factors for a LCT, this study does not aspire to explain a transition. Therefore this critique is not relevant to this study.
Too little attention put on places and contexts McCauley and Stephens (2012) along with Gibbs and O'Neill (2014) argues that too little attention is put on the places and context in which transitions occur. To be able to provide causal explanations of transitions spatiality is needed (Gibbs & O'Neill, 2014, p. 212). Moreover, if the MLP should be used to understand and promote transitions in a specific location, the framework has to be less abstract and focus more on places and contexts (McCauley & Stephens, 2012, p. 217).	This critique has not yet been responded to.	According to Gibbs and O'Neill (2014) the lack of context and spatiality of the MLP makes it unable to explain what causes transitions to happen. However, this study does not aspire to explain the transition to FBB, but solely identify drivers and barriers of the transition. Therefore the study is more exploratory than explanatory, which is why this critique is of little importance to this study.
Poor conceptualization of processes of final consumption According to McMeeking & Southerton (2012) the MLP put too much focus on special users who are early adopters of new technologies and fail to recognize the mass of ordinary consumers (McMeeking & Southerton, 2012, p 347). As they see it; *"ordinary users are viewed as a relatively homogeneous group trapped within the incumbent socio-technical regime; their attachments to existing technologies provide stability to that regime and are a source of resistance to radical innovations. Changes in mass consumption, within this class of ordinary users occur in a reactive fashion only after disruption at the landscape level and when the innovative niche level work of avant garde producers and 'special users' has gained some momentum."* (McMeekin & Southerton, 2012, p. 348).	McMeeking & Southerton (2012) argues that the main focus of the MLP has been on the producers, their innovations and on political governance that have the possibility to influence transitions, not on transitions in consumptions. Therefore they suggest that a practice based approach could be combined with the MLP to add more focus on final consumption. Practice theory can be used to study what people do as well as why and how their practices influence their consumption (McMeeking & Southerton, 2012).	As this study aims to identify enabling and hindering factors connected to final consumption, this critique is justifiable. Therefore, practice theory as a means to explain end consumption is explained in more detail in the end of this chapter and incorporated into the analysis.

Appendix V.

A link to the Perform project: https://perform-bioeconomy.info/

The survey was set up accordingly with the pictures below, photos taken by Cecilia Mark-Herbert. In the pictures the setup of the computers can be seen and how it looked when some respondents were filling out the survey. As can be seen in the pictures the survey station was set up just before entering the shopping area of IKEA Uppsala and just outside the kids playing area which was closed during the survey operating hours.

Appendix VI.

Table 16. Means for all survey questions

Question	Mean (N=204)
I am familiar with wooden multi-storey buildings	4,20
Wooden multi-storey buildings are faster and cheaper to build than steel or concrete ones	3,88
Wooden multi-storey buildings do not last as long as steel or concrete buildings	3,20
Wooden multi-storey buildings need more repairs and maintenance than steel or concrete buildings	3,21
Wooden multi-storey buildings need less insulation than steel or concrete buildings	3,60
Wooden multi-storey buildings are healthier to live in than steel or concrete buildings	4,42
Wooden multi-storey buildings have a higher risk of fire than steel or concrete buildings	3,87
Wooden multi-storey buildings are less harmful to climate than steel or concrete buildings	4,45
Wooden multi-storey buildings do contribute to global deforestation and biodiversity loss	3,26
Wooden multi-storey buildings do generate income and well-being to more people than steel or concrete buildings	4,01
I am familiar with how forests store carbon	4,59
Managed forests have great potential to reduce carbon emissions	4,44
How forests are being managed can threaten carbon stocks in forests	4,50
Land/forest owners need support to maintain and manage forests	4,67
Land/forest owners must be compensated monetarily for storing carbon in forests	4,19
I know the meaning of forest-based bioeconomy	3,66
Forest-based bioeconomy decreases our dependency on oil and fossil fuels	4,69
Forest-based bioeconomy increases our economic self-sufficiency	4,69
Forest-based bioeconomy generates new jobs and well-being in rural areas	4,76
Forest-based bioeconomy mainly benefits large companies and their shareholders	3,29
Forest-based bioeconomy products should be of domestic origin to be more sustainable	4,46
Agriculture-based bioeconomy is more important for society than forest-based bioeconomy	3,44
The risks of forest-based bioeconomy are greater than its benefits	2,88
The risks of forest-based bioeconomy must be understood before we fully embark on it	4,02
All different views must be seriously considered when forest-based bioeconomy develops	4,58
Use of fossil fuels and non-renewable materials must be reduced as soon as possible	4,85
Environmental regulation limits overall economic development and growth	3,77
Humans will be able to solve environmental problems when technology develops	4,05
Despite our special abilities, humans are still subject to laws of nature	5,12
Humans have the right to modify the natural environment to suit their needs	3,07
The balance of nature is very delicate and easily upset	5,07
I trust information on forest-based bioeconomy from government officials	3,76
I trust information on forest-based bioeconomy from researchers and experts	4,69
I trust information on forest-based bioeconomy from environmental and civic organizations	4,24

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