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Multi-Storey Timber-Based Buildings: An International Survey of Case-Studies with Five or More Storeys Over the Last Twenty Years

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Kurzfassung

Seit Anfang der 2000er Jahre kann in mehreren westlichen Ländern eine stetige und heterogene Verbreitung des mehrgeschossiger Holzgebäude festgestellt werden. Diese Dissertation bestätigt diese Observation, denn zwischen der Realisierung des ersten fünfstöckigen Gebäudes im 2004, des ersten fünfstöckigen Gebäudes bis hin in Jahr 2019, wurden mindestens 196 weitere Holzgebäude gebaut. Nachdem viele Fallstudien erstmalige untersucht wurde, besteht das Ziel dieser Dissertation darin, die verschiedenen internationalen Ansätze zu kategorisieren und zu definieren, was sie sind die Antriebe, die deren Design beeinflussen haben. Einige Lösungsansätze können ebenfalls identifiziert werden.

Weil das Forschungsthema eine noch junge Entwicklung im akademischen Raum darstellt, definiert diese Arbeit was mehrgeschossiger Holzgebäude tatsächlich sind. Nachdem folgt die Literaturdiskussion und fährt mit der Auswahl der Fallstudien nach definierten Höhen- und Strukturkriterien fort. Mit der vollständigen Liste der Gebäude, die Arbeit analysiert zunächst die Gestaltungsmerkmale aller Fallstudien, um zu untersuchen wie diese Projekte gebaut werden. Die Analyse umfasst elf strukturelle Kategorien, in die jede Fallstudie eingeteilt und beschrieben wird. Die Analyse zeigt, dass es viele Designunterschiede zwischen den beteiligten Ländern gibt.

Der Zweck des zweiten Schritts bestand darin, zu verstehen, von wem und warum diese Gebäude gebaut wurden. Um diese Frage zu beantworten, fährt die Arbeit mit der Kontextanalyse jedes Landes fort. Der zum Zeitpunkt der Projekte bestehende Rechtsrahmen wird beschrieben, der Schwerpunkt liegt jedoch auf den Stakeholdern und R&D-Konzepten, welche an der Realisierung der ausgewählten Fallstudien beteiligt waren. Darüber hinaus wurden die genannten Gründe für die Wahl einer Holzstruktur sowie die öffentliche und private Typologie des Auftrags untersucht. Die Kontextanalyse zeigt, dass der rechtliche Rahmen häufig die notwendigen Regeln für den Bau mehrgeschossiger Holzgebäude festlegt. Diese Beobachtung wird auch in der Fachliteratur bestätigt. Die Rolle der Stakeholder ist jedoch nicht zweitrangig und es gibt klare Abhängigkeitsstrukturen zwischen der Mehrheit der Fallstudien und den beteiligten Fachleuten. Während Privatkunden in den meisten Fällen häufig die eigentlichen “Drivers” sind, gibt es mehrere Länder, in denen öffentliche Initiativen die Haupttreiber sind. In einigen Fällen spielten die Eigenschaften von Holz eine entscheidende Rolle bei der Auswahl der Kunden.

Diese Dissertation fügt weitere wertvolle Informationen in Bezug auf die konstruktiven und kontextuellen Merkmale mehrgeschossiger Holzgebäude, welche in den letzten fünfzehn Jahren gebaut wurden, hinzu, um so die Unterschiede und Gemeinsamkeiten zwischen den einzelnen beteiligten Ländern aufzuzeigen. Mehrgeschossige Holzgebäude sind komplexe Phänomene, welche stark von der Nation in welcher sie errichtet werden beeinflusst werden. Gleichzeitig konnten internationale Design Trends und wichtige Akteure identifiziert werden, die die Designlösungen und Umsetzung dieser Gebäude erheblich beeinflussten.

Abstract

Since the early 2000s, there has been a steady and heterogeneous proliferation throughout several western countries of multi-story timber-based buildings. This thesis confirms that since the first five-storey building was realised in 2004, at least 196 others were built until 2019. With many of these case-studies having been researched for the first time, the goal of this dissertation is to categorize the different international approaches and to define what are the drivers which had an effect on the design.

Because the research topic is a recent development in academia, this thesis defines what multi-storey timber-based buildings actually are, and, after the discussion of existing literature, proceeds with the selection of the case-studies according to defined height and structural criteria. With the complete list of the buildings, the thesis first analyses the design characteristics of all case-studies, in order to research how these projects were built. The analysis includes thirty-two structural categories in which each case-study is classified and described. The analysis was able to show that there are many design differences between the countries involved. Some clusters of solutions can also be identified.

The purpose of the second step was to understand by who and why these buildings have been built. In order to answer these questions, the thesis proceeds with each country's contextual analysis. Regulatory framework in place at the time of the project are described, but the focus is given on the stakeholders and R&D concepts involved in the realisation of the selected case-studies. Furthermore, the declared reasons for choosing a timber structure, along with the public and private typology of the commission were also researched. The contextual analysis shows, as the literature confirms, that the legal framework often sets the necessary rules for building multi-story timber-based buildings. However, the role played by the stakeholders is not secondary, and there are clear patterns of interdependence between many case-studies and the professionals involved in their construction. While private clients are often the actual drivers behind the majority of the cases, there are several countries in which the leading role is played by public initiatives. In some cases, the intrinsic properties of timber played a decisive role in the choice of the clients.

This dissertation adds further valuable information regarding the constructive and contextual characteristics of multi-story timber-based buildings built over the last fifteen years, in order to show the differences and commonalities between each country involved. Multi-storey timber-based buildings are a complex phenomenon, which really depend on the nation in which they were built. At the same time, it was possible to identify international trends in their design, and major players which considerably influenced the design solutions and realisations of these buildings.

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Thanks to the office Architects Collective in which I worked parallel to my dissertation. Thanks to the partners which favoured my decision on pursuing a PhD research, and to all my colleagues which demonstrated interest and suggestions for the proceeding of my work.

During my years of research I met and discussed with many timber experts from all over the world and professionals from which I learned so much. Mentioning all of them would be impossible in this context, but this work was also possible thanks to all the insights that many people shared with me.

So much valuable material has been shared online, and I am thankful to all the professionals, students, and passionate contributors, which helped me to enrich this work. Sharing information is so important for collaborating and learning from each other, and the attitude which so many people demonstrated was really impressive.

This work is dedicated to my family. Thanks Mamma, Babbo, and Ily for always believing in me in all these years far from home.

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List of abbreviations

BIM: Building Information Modeling

BREEM: Building Research Establishment Environmental Assessment Method

CLT: Cross Laminated Timber

CO_2: Carbon Dioxide

DLT: Dowel Laminated Timber

EWPs: Engineered Wood Products

EU: European Union

GHG: Green House Gasses

GLRS: Gravity Load Resisting System

Glulam: Glued Laminated (Timber)

LEED: Leadership in Energy and Environmental Design

LLRS: Lateral Load Resisting System

MTB(s): Multi-storey Timber-based Building(s)

n/a: Not Applicable

NLT: Nailed Laminated Timber

OECD: Organisation for Economic Co-operation and Development

UK: The United Kingdom

US: The United States (of America)

WCTE: World Conference on Timber Engineering

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Chapter 1

Introduction

The current generation of young architects and engineers are living through a series of environmental and technological changes which have created a much different design scenario compared to previous generations. The dominant role of steel and reinforced concrete as main building materials is now challenged by the rising awareness of climate change and the consequent decarbonisation targets at every level of the society. Since the end of the 20^{th} century, the question of how to deal with an increasing scarcity of resources has been central, and the need for renewable materials became prominent, particularly in the construction sector. A possible solution to these environmental challenges is represented by the development of Engineered Wood Products. These products allowed the realisation of new tall timber structures, which in this thesis will be called *multi-storey timber-based buildings* (MTBs). Since the very beginning of this century, the number of these buildings has grown worldwide, and apparently, in different ways. But the most striking characteristic is their height. Mid-rise timber structures were not uncommon in the past, but today's projects are ten-storey tall, some even exceed seventeen storeys, something unimaginable just decades ago.

It is no wonder that academic publications, books and media describe and celebrate these new buildings, as if we are talking about a "renaissance" of timber, with a particular emphasis being placed on the technological and structural achievements (Mayo, 2015). The underlining impression from all these sources, is that we are experiencing a similar global phenomenon of building high-rise projects with timber structures. However, very little is known about these types of buildings in a world-wide comparative perspective. Are the built MTBs the same type of structures? And why they are built in so many countries of the world? Because they are a recent phenomenon, they have been mainly compared with other nationally or regionally similar buildings, leaving the differences (or similarities) between the world's projects out of the analysis. In light of these premises, we should have a closer look at the state of the art of these buildings, and consider them from a global perspective. Therefore, this dissertation will first define what multi-storey timber-based buildings are, and then will proceed to describe their main characteristics in order to understand the phenomenon and the factors which influence both their design and realisation.

1.1 What is a Multi-Storey Timber-Based Building (MTB)

Before proceeding with the dissertation, it is necessary to clarify why the term *multi-storey timber-based buildings* (MTBs) is used here. When looking at the analysis of the literature, the definition of a multi-storey building with a timber structure is not clear. Several studies refer to *tall wood buildings*, others *multi-storey timber buildings*, others *wood-frame multistory* and others varies on specific terms like *wood-timber* or *storey-story*. The topic of the terminology is also directly linked with other two related aspects in the definition of these structures: height and ratio of timber as structural elements in the structure. Like for the previous term, the literature is heterogeneous in the definitions of height and structural criteria. Therefore, a clarification is necessary.

1.1.1 Definition of the Term "Multi-Storey"

The literature refers to these types of buildings in various ways, as Table 1.1 shows. The table collects a sample of the main academic and grey literature sources used for this dissertation and shows the heterogeneity of terms the literature refers to. Many sources use the term *multi-storey timber buildings*, but there are other common terms like *wood-frame multistory* or *wooden multistory building*. If it seems like some terms are used less often than others, it is because there is not a clearly prevalent term. In light of these differences, the author decided to follow the use of *multi-storey timber*, which is one of the most common terms in the literature. The terms *-storey* or *-story* are used arbitrarily in the literature. In this dissertation, the author chose to use the first term. According to Merriam-Webster Dictionary, the term *multistory* means *"having more than two stories"* or *"having many stories"* (Merriam-Webster, n.d.). In this dissertation, MTBs were referred to buildings with a height of two or more storeys. However, in the Section 4.2.1 dedicated to the survey's criteria, the height limit will be set to a minimum storey-threshold of five storeys (included) in order to make the survey feasible. The reasons for this will be explained in subsequent chapters.

Table 1.1: Terminology used in Literature

Term	**Sample of the literature**
Multi-storey (-story) timber building (or construction)	(Lattke and Lehmann, 2007) (Mahapatra and Gustavsson, 2008) (Lehmann, 2012) (Riala and Ilola, 2014) (Gosselin et al., 2015) (Ruuska and Häkkinen, 2016) (Zumbrunnen, 2017) (Kuzman and Sandberg, 2017) (Kaufmann et al., 2018) (Markström et al., 2019)
Multi-storey timber-frame construction	(Kairi, 2005) (Nord et al., 2011) (Xia et al., 2014)

Wooden (or Wood-based) multistory building (or construction)	(Mahapatra and Gustavsson, 2009) (Eliasson and Thörnqvist, 2010) (Östman and Källsner, 2011) (Mikkola, 2014) (Anttonen, 2015) (Federation of the Finnish Woodworking Industries, 2019) (Toppinen et al., 2019)
Wood-frame multi-story construction (WMC)	(Gustavsson et al., 2006) (Mahapatra et al., 2012) (Hurmekoski et al., 2015) (Hurmekoski et al., 2018) (Vihemäki et al., 2019) (Lazarevic et al., 2020)
Tall Wood (-en)	(Green and Karsh, 2012) (Salvadori, 2017) (Green and Taggart, 2017) (Wiegand, 2019)
Tall Timber	(Foster et al., 2017) (Kuzmanovska et al., 2018) (Landel, 2018)

1.1.2 Definition of the Term "Timber-Based"

Defining the materiality of MTBs is debatable, and the parameters are not the same for every publication (Wiegand, 2019). However, in the academic discussion, the main contributor to the definition of the materiality of these buildings is their structure (Brege et al., 2015) (Hurmekoski et al., 2015) (Foster et al., 2017). Section 5.2.1 of Chapter 5 is dedicated to the detailed discussion of the structural academic debate. Here, it is enough to say that the buildings can be classified by their lateral and gravity load resisting systems. The combinations between timber and other materials are many, and the ratio of the materials and their structural role (main or secondary) often affects the definition of the materiality of these buildings.

In order to give a definition in this regard, in this dissertation multi-storey timber-based buildings are considered buildings where the load bearing structure is for the most part made of Engineered Wood Products (EWPs) or EWPs-based. EWPs are *"timber products which includes a range of derivative wood products which are manufactured by binding or fixing the strands, particles, fibres, or veneers or boards of wood, together with adhesives, or other methods of fixation to form composite material."* (Dataholz, n.d.). These products can be combined with other EWPs or with concrete and steel, forming hybrid combinations called "EWPs-based". Other types of hybrid combinations are formed by steel braces inside an all-timber structure, a concrete podium on the top of which an all-timber structure is erected, or a concrete core which is connected to a timber structure. In this regard, the existing literature seldom deals with these hybrid combinations from a terminology perspective. Many buildings are called *Multi-Storey Timber* or *Tall Wood* even if they have a considerable part of their structure made of concrete or steel. Buildings with a concrete core for example, or hybrid floor slabs (CLT-concrete) are often included in books or studies which mainly refers to timber buildings (Hurmekoski et al., 2015) (Gosselin et al., 2015) (Green and Taggart, 2017) (Kaufmann et al., 2018). There are also several projects built with only EWPs (excluding

steel connectors and concrete foundations), but this thesis will prove that the vast majority of the selected case-studies are instead *timber-based* buildings. By acknowledging these differences, and having the goal of using a clear definition of these buildings, the author opted to define all the case-studies as *multi-storey timber-based buildings* (MTBs), considering this term as the most inclusive one.

The definition of MTBs given here does not include lightweight timber frame buildings, which are not treated in this dissertation. The clarification is necessary because there are countless multi-storey buildings built with a lightweight timber frame system. This construction technique is particularly adopted in North America, but there are similar systems used in other parts of the world, too. Panoramic timber towers, historical buildings rebuilt in timber and lightweight multi-storey timber buildings which use EWPs as secondary structural elements, are also not considered in this research.

1.2 Problem Statement and Main Research Questions

This dissertation starts with the observation of the heterogeneity of the phenomenon of MTBs. It is evident that the number of these projects is growing in some countries, as are their heights. Furthermore, through a more detailed study, it is possible to recognise some design similarities between projects. In this regard, very few comparative studies have been made on completed MTBs. Besides including completed buildings, the most recent of them includes proposed projects which do not fully represent the current state of the art of MTBs (CTBUH Journal, 2017) (Salvadori, 2017) (Kuzmanovska et al., 2018). Other studies compared different examples but were not focused specifically on MTBs, or did not include enough examples to consider them representative today (Lehmann, 2012) (Holt and Wardle, 2014) (Smith et al., 2015).

Aside from comparative surveys, the academic works that have studied the phenomenon tend to be focused on a limited number of projects, or single countries (Lattke and Lehmann, 2007) (Roos et al., 2010) (van Egmond, 2011) (Lehmann, 2012) (Gustavsson et al., 2014) (Riala and Ilola, 2014) (Gosselin et al., 2015) (Hurmekoski, 2016) (Vihemäki et al., 2019). Some research is focused instead on a European or North American context (Mahapatra and Gustavsson, 2009) (Östman and Källsner, 2011) (Mahapatra et al., 2012) (Hurmekoski et al., 2015). Interestingly, a proper perspective on MTBs is given by several books which provide an overview of not only completed projects, but also of some contextual, technical and structural insights (Mayo, 2015) (Green and Taggart, 2017) (Kaufmann et al., 2018).

A sentence in Vihemäki et al. (2019) properly summarises the major findings of the literature on the topic: *"(...) the high autonomy of construction projects and wide regional variations in construction and housing markets, policies and technical specializations mean that the change prospects of the construction sector may vary much even across a country. These issues deserve further research, involving wider geographic coverage, more cases as well as city/municipality level analysis, for*

enabling a more comprehensive comparison." (Vihemäki et al., 2019) As Vihemäki et al. (2019) observed, in order to have a better understanding of the state of the art of MTBs, more cases must be included in a global comparative study as well as the number of countries involved.

The conclusions of some studies suggest the existence of macro-regional differences in the market for MTBs (Hurmekoski et al., 2015) and that there are several categories involved in the design of the structure of these buildings (Brege et al., 2015) (Foster et al., 2017) (Kuzmanovska et al., 2018). The literature also adds that the potential drivers behind these differences are due to the regulatory framework of each country, and their industry (Roos et al., 2010) (Riala and Ilola, 2014) (Gustavsson et al., 2014) (Hurmekoski et al., 2015) (Hurmekoski, 2016) (Vihemäki et al., 2019). What the literature lacks, are studies of the players and influences involved in completed projects. What is not clear, are the connections between the built MTBs and their stakeholders - which includes architects, engineers, contractors, industry, and clients - and how the stakeholders influence the realisations of MTBs. Is it true that regulatory frameworks are the main drivers of differences between these buildings, or do the professionals involved also determine some differences? Therefore, in this dissertation a consistent part is dedicated to the study of the relationships between the stakeholders and the case-studies due to the hypothesis of this thesis being that exist patterns of interdependence between them. By showing that the stakeholders can and do affect the design of a building, this dissertation will point the attention of the academic discussion to the role that the stakeholders play in the realisation of future MTBs and will shed light on how the stakeholders can affect the design of MTBs.

In light of all these observations, there is a gap in the literature that needs to be filled and therefore the main questions this thesis will answer is: how were MTBs designed and what factors influenced their differences and similarities? The author hypotheses that there are national differences in the realisation of MTBs and, even if the literature says that the drivers of these differences are mainly the regulatory framework of the countries, the hypothesis goes even further to say that there are other drivers which affect the differences of MTBs' design. In this regard, by evaluating the stakeholders involved (public and private), it will be possible to determine if the repetitions and similarities observed in a first design analysis will be explained by the analysis of the designers involved.

Additionally, by establishing this thesis as a comparative survey, it will be necessary to clarify where and when were MTBs built. The selection of the criteria of the survey will be explained in Chapter 4. Finally, this dissertation would be incomplete without the explanation of two related questions: why build MTBs and why it is possible to build MTBs today. The literature on the latter is lacking a clear explanation of how the main EWPs today came to be and this dissertation will clarify some key events related to them. By answering these two questions, the dissertation will provide a complete overview of the main reasons why these buildings are growing, and will constitute the necessary foundation premises which will then justify the entire work.

1.3 Research Methodology

In light of the comparative nature of the research questions, the main part of this dissertation is designed as a comparative survey. Each of the chapters of this thesis answer one main research question, as Table 1.2 shows. After Chapter 2 and Chapter 3, which introduce the topic of MTBs from different perspectives (environmental and historical), the core part of this research begins. This part includes Chapter 4, Chapter 5, and Chapter 6.

Table 1.2: Chapter division and main Research Questions

Chapter	**Title**	**Research Questions**
1	Introduction	Introduction and definition of MTBs
2	Rationale for MTBs	Why Build MTBs?
3	The Historical Development of Timber Construction	Why it is possible to build MTBs today?
4	Survey criteria	Where and When Were MTBs Built?
5	Design Analysis	How were MTBs designed?
6	Context Analysis	Why were MTBs built and Who built them?
7	Conclusions	Main findings and further researches

1.3.1 Research Strategy

The problem statement of this dissertation incorporates three main topics: survey criteria, design analysis and context analysis. To investigate the research topic and answer the main research questions, the applied methodology has been developed throughout subsequent steps of investigation:

1. **Step 1: Selection of the case studies (Chapter 4)**

   The first step of this research determines the case-studies which will be considered in this study. After the analysis of the existing literature on surveys regarding MTBs, the main lessons learned were collected and discussed. In light of this learning, the survey's criteria are set and applied to the data sources of this dissertation. Information from data sources was recollected in form of a descriptive chart. Scientific papers, PhD dissertations, official published MTBs lists and websites databases were the starting point for the lists which grew thanks to deeper research on other grey literature and internet sources which included conference papers, local news and timber websites. When data saturation was reached, the sample was considered complete. This process will result in the selection of 197 case-studies completed in 18 countries from 2004 to 2019. In this chapter a necessary level of analysis is carried out. In order to reorder the case-studies, the chapter locates the projects and adds additional information to them such as year of completion and number of storeys. The case-

studies are then arranged in 15 different groups according to their main continent (Europe, North America and Others) and by alphabetical order of the country to which they belong. Within each country, the case studies are organised in chronological order. Due to the low number of case-studies, two groups were created. A first group formed by Belgian and Dutch case-studies called "Benelux", and a group formed by Chilean, New Zealand and Taiwanese case-studies called "Other countries".

2. **Step 2: Design Analysis (Chapter 5)**

   The second step of the investigation is carried out in Chapter 5. The goal here is to understand how the selected case-studies were built and if there are some differences or similarities which are worth taking note of. Before the analysis, the chapter begins with the literature review of the existing design categorisation approaches and defines a set of 32 structural categories with which all the 197 case-studies are described. In light of the comments made on the existing survey's design categorisation, the chapter proceeds to describe the main categories of analysis which will be used for the analysis of each case-study. Because the goal of the research is to investigate the geographical differences, the case-studies are kept divided into their countries following the order set in the previous chapter. At the end of Chapter 5, all of the major findings are compared and discussed.

3. **Step 3: Context analysis (Chapter 6)**

   The third and last step analyses the context in which each case study was influenced. As with the previous chapter, this one also begins with a literature analysis of the contextual studies on MTBs. It then proceeds with the description of the main categories of analysis for each case-study. These are referring to the client and the public or public influence in the projects, the motivations and the stakeholders involved in the buildings. The scope of this step is to first provide a proper overview of the existing influences in the selected MTBs, and at the same time to explain the reasons for the similarities and differences observed in Chapter 5. The central part of the chapter is dedicated to both the description and the explanation of the MTBs according to the categories of analysis. A graphical representation of the key players in each country will be made at the end of each country's section. At the end of the chapter, as with the previous one, the main findings are compared and discussed.

The conclusion of this thesis will summarise the main findings observed in all the study. There are repetitions, influences, and a pattern of interdependence between the case studies and some stakeholders, due to R&D programs, common design choices and several other factors. At the end of this work, it will be clear that there are both international trends and national differences in the construction of MTBs, and some of these differences are related to the stakeholders involved in the projects.

1.3.2 Data Sources

Below are reported the main data sources used to built up the list of the case-studies. When possible, triangulation was used to obtain as many accurate qualitative and quantitative data points as possible. These sources are heterogeneous. Besides common academic and grey literature, websites and online databases between others were researched. These data sources were used both for the selection of the case-studies and for the collection of quantitative and qualitative data on each specific case-study necessary for the analysis in Chapter 5 and Chapter 6.

- **Academic papers:** many papers were published in the last two decades on MTBs, mainly focusing on technical and structural aspects. Some academic papers are dedicated to structural categorisations or similar structural aspects and these studies are discussed and described in more detail in section 5.1 in Chapter 5. Studies on factors which influence MTBs, such as regulatory framework, the MTB market, drivers and policies are discussed in section 6.1 in Chapter 6.

  Alongside this literature, some papers were published in which several MTBs were analysed and compared (Lattke and Lehmann, 2007) (Lehmann, 2012) (Gosselin et al., 2015) (Hurmekoski et al., 2015). However, excluding Lehmann (2012), none of the studies were considered surveys, but were rather used to gather qualitative information on the case-studies described.

- **Grey literature:** grey literature sources are government or institution reports, issues papers and master or doctoral thesis. Several technical reports on MTBs were made (Green and Karsh, 2012) (SOM, 2013), as were other governmental or institutional reports (Mahapatra and Gustavsson, 2009). Some master theses (van Egmond, 2011) (Salvadori, 2017) (Wiegand, 2019) and doctoral theses (Falk, 2005) (Kist, 2013) (Hurmekoski, 2016) were also considered in this dissertation.

  There are several conferences which provided valuable data and insights for the case-studies related to timber engineering and construction. One of the main sources for peer-reviewed articles is the World Conference on Timber Engineering (WCTE). WCTE takes place every two years, and rotates continent (Europe-Asia-America) for each conference. With the first conference taking place in 1988, it is one of the oldest organised conferences on timber engineering. Another relevant source of information were the papers submitted to the yearly conferences for the Forum Holzbau. In the past few years Forum Holzbau became a franchise which holds events in several countries across Europe, and its main conference, the International Forum Holzbau (IHF) arrived in 2019 as its 25^{th} edition. The conference papers are not peer-reviewed, but are presented by the same professionals involved in the case-studies. These presentations provide valuable information on technical, constructive and contextual insights.

- **Books:** besides traditional academic papers or reports, some published books were considered as additional sources of information. The information provided were not only regarding

the context for MTBs or the history of timber construction, but were also analysed for qualitative and quantitative data of some built case-studies.

Mayo (2015) is the first comprehensive publication on MTBs, with the author reporting the development of timber in multi-storey construction throughout several countries. This book, as well as the books following, provides the reasons for building with wood, along with other historical events which led to the realisation of MTBs. Importance is placed, as in this dissertation, on detecting the context in which the twenty-seven case-studies were realised, by sorting them by country. Even if the goal of this book was not to make a comparative survey, the work suggests throughout the design analysis of the case-studies, that there are some differences in the construction of MTBs.

Green and Taggart (2017) includes twelve built case-studies with a minimum height of four-storeys. The case-studies are divided according to the structural categorisation made in the book, respectively: panel systems, frame systems and hybrid systems, which will be discussed in Section 5.1 in Chapter 5. As with the previous books, this publication does not limit the description of the case-studies, but emphasises the reasons for building with timber, it gives an overview of the EWPs available to designers and make some structural considerations.

Waugh Thistleton Architects (2018) describes the design and provides insights of 100 CLT-based projects in the United Kingdom. Qualitative and quantitative data were provided by this publication, as were the name of the stakeholders involved.

Finally, Kaufmann et al. (2018) is, by the end of 2020, the most specific comprehensive technical manual on the context and practice of MTBs. Following the previous edition (Herzog et al., 2003), the Manual describes twenty-two case-studies built in different countries. The Manual follows the entire process of wood from the material characteristics to the building solutions available. The case-studies include single-houses, new MTBs, 3D modules and renovations of multi-storey buildings with timber.

- **Websites of stakeholders:** parallel to these databases, valuable data was gathered from the websites of stakeholders like architects, engineers, timber manufacturers, and general contractors (or sub-contractors) involved in the case-studies. Timber manufacturers' websites in particular proved to be updated and provided both qualitative and quantitative data on built case-studies. Some of them have internal referential libraries which made it possible to discover and add projects which were unknown or less studied in academic literature.

- **Online Databases:** besides this body of academic research and published surveys, some online databases were considered relevant to the research on built MTBs. Table 1.3 shows that there are several online databases which collect information on built and planned timber projects. The majority of these online databases are a separate section of timber-specialized agencies and websites for the local promotion of timber construction. They do not attempt to make comparative studies between the case-studies. Usually, they are focused on case-studies built in one country, and rarely are they intended as databases exclusively for MTBs. Therefore, not all the projects listed in these databases were directly considered in the dis-

sertation's case-study-list because they did not meet the survey's criteria (mainly the height threshold).

Table 1.3: List of the online-databases used as sources

Website *(name)*	**Case-studies** *(number by end 2020)*	**Status** *(category)*	**Minimum height-treshold** *(storey)*
Puuinfo.fi	26	Built	Two-storey
Swedishwood.com	36	Built	Three-storey
Thinkwood.com	57	Built	One-storey
Timberarchitecture.com	49	Built and planned	Seven-storey
Woodarchitecture.fi	25	Built	Two-storey
Woodforgood.com	48	Built	One-storey
Woodsolutions.com.au	17	Built	Three-storey
Woodskyscraper.com	92	Built and planned	Five-storey

- **Online newspapers and media articles:** online sources like newspapers and other media supported the academic and grey literature. The advantage of these media sources is that they are usually up to date, and provide a wide variety of information. These sources provided valuable insights on the ongoing projects, along with photos of the construction sites of the buildings, from which it was possible to understand structural or other design choices made by the team. Other types of sources like Timber Online[1] or Holz Kurier[2], are more focused on the market situation and context of timber construction. They provided valuable insights along with qualitative and quantitative data. An important role played by these sources was to report the declared influences in the choosing to build some of the case-studies. Local news found online also provided valuable interviews, opinions and comments of accountable professionals involved in the case-study reported.

- **Correspondence with stakeholders:** in the case in which the information of a case-study was not found or considered incomplete, the author directly contacted some stakeholders involved in the design via email from August 2020 until December 2020. A total of 30 projects were successfully supplemented with information provided by the 27 successful correspondences. The goal of this correspondence depended on the type of information that was lacking or uncertain. The most common question asked referred to the motivations behind building certain projects. Other times, specific structural design information was asked, such as which EWPs were used, missing quantitative data, or for photographic material.

  In addition to this correspondence, since the beginning of the PhD research in April 2018 through December 2020, other information was obtained through face-to-face meetings or video-conference calls with some stakeholders.

[1] www.timber-online.net
[2] www.holzkurier.com

1.4 Reading Guide

The last section of the present chapter is dedicated to providing a brief outline of the structure and content, and an explanation of the research design. After this introductory part, the first chapter explains why there are good reasons for building MTBs, and the following chapter explains how it was possible to conceive them. The dissertation will then turn to the main researched aspects with the chapter on the survey criteria, design analysis, and analysis of the context. The conclusion chapter closes the discussion by collecting the main findings and proposing further research. Below, the chapters are listed with a brief description in order to guide the reader through the structure of the dissertation.

Chapter 2 - Rationale for MTBs

The second chapter makes the case for the realisation of MTBs. The chapter focuses on the four main reasons that lead to the consideration of building multi-storey buildings with timber: the world situation regarding CO_2 emissions, the future growth of the world's population, the current status of the building industry, and the indoor benefits of timber. CO_2 has been a topic since 1970. It was a game changer, and sparked a revolution in how buildings are constructed. More and more attention was given to sustainability during and after the building site, with topics like efficiency and passive standards that were successfully implemented in only a few years time. At the same moment, the world's population doubled in less than a century, and for the first time in history, more people lived in cities than in the countryside. The overall effect of this high concentration of people in cities leads to the special focus on multi-storey buildings. These buildings are going to be architecturally and structurally advantageous in an urbanized world. The favourable opinion of sustainable buildings, and the already high and potentially increasing demands for complex and tall buildings are positive elements which can be utilised in one of the least developed and least productive industries: the construction industry. The lack of investment and the delay for building methods which were more time and cost-efficient, led the industry to find itself unprepared for the challenges of the 21st century, which are challenges that cannot be postponed. Furthermore, exposing timber surfaces inside the buildings has been proven to have many advantages for the users. The conclusion of the chapter leads to the need to understand the typology of MTBs. These structures merge in them all the main constructive challenges of this century: building sustainably mid-rise and high-rise buildings, along with efficient processes.

Chapter 3 - Historical development of timber in construction

The third chapter gives an overview of the history, tradition, and development of timber usage and modern approaches to industrial production and systematisation. Before understanding the context which influenced the already built MTBs, it is necessary to understand how it was possible to conceive such structures. The chapter begins with a brief recollection of the main tall timber buildings built in the last two millennia by different cultures and historical moments. For a long

time in construction history, timber was the main building material and some buildings built with timber reached considerable heights. It was only in the beginning of the 19th century that other materials started to emerge. The focus of the chapter then switches to the research on timber and construction development between the 20th century and the beginning of the 21st century. The product development that took place, together with the new sensibility toward timber and sustainable construction, led academic researches and the timber industry to the mass production of more and more timber and timber-based products, supporting the revitalized design interest in timber buildings. Thanks to a newly industrialised set of timber-based products, professionals in the construction sector and the timber industry began to develop new concepts, and by the turn of the millennia the first generation of MTBs was completed. At the beginning, these buildings were composed of few storeys but after just a few years, in the early 2000s, the first five-storey timber-based building was completed in Austria. This chapter portrays the technological steps and some key figures which helped timber achieve such technological advances.

Chapter 4 - Survey criteria and definition of the case studies

The fourth chapter defines the group of case-studies which will be analysed throughout the dissertation and describes them according to their location and their completion date. The literature on comparative surveys is scarce and are heterogeneous in the choice of the criteria. Height, structure and status of the projects differ between the existing surveys. However, some valuable insights can be learned from the previous studies, and it is in light of this that the author chose his survey criteria. These are considering buildings up to and including five storeys which were completed between 2004 and 2019. Through the application of these criteria to the data sources used in this dissertation, 197 case-studies in 18 different countries were selected. These projects are divided into three groups (Europe, North America and Other countries), located in a map and listed with similar information like completion data and number of storeys. The location and the completion date of these projects are then presented graphically. MTBs are a OECD phenomenon, mainly concentrated in even fewer countries (five of the 18 countries have less than four case-studies), and they are a recent practice, with the majority of the case-studies completed in the last four years of the survey (2016-2019).

Chapter 5 - Design Analysis

The fifth chapter deals with the design properties of MTBs. The chapter begins with an overview of the existing literature on design analysis and categorisation, comparing and discussing the scarce sources. Particular attention is given to the subdivision of structural categorisation, along with how each system differs. The starting system of categorisation in "panelised", "post-and-beam", and "3D modular element", is enriched and described adding all the hybrid-material combinations observed in the case-studies. Other topics related to the structure are also analysed, namely the use of EWPs and EWP-based products. After the structural categories, other design categories like program, exterior cladding, indoor timber exposure, and building volume are described. Every country is analysed in a separate section in which the country's case-studies are described individually. The

conclusion of the chapter recollects the main findings and observations related to the purpose of the analysis, showing graphically, how each country differs from one another. There are design differences between clusters of countries (like North America or Scandinavia), and even within each country there are differences which make it difficult to classify the design of MTBs as a common regional - and in some cases even national - practice. At the same time, Chapter 5 proves that there are some international trends in the construction of MTBs, which in part justify the media celebration of CLT as main EWPs.

Chapter 6 - The Context

Having defined what are the main different design characteristics of the case-studies, the sixth chapter analyses the contextual environment and influences in each case-study. The analysis of the literature evidenced the lack of analysis of the players involved in each MTBs, and lacked a comparison of influences and recognisable patterns between case-studies and stakeholders. As stated in the literature analysis, there are no studies to date which have made such a comparison. The dissertation therefore analyses the clusters and the relationships between all these players and summarizes them with conceptual schemes. The outcome of the analysis differs for each country and presents evidence of repetition and clusters of interdependence. The legal framework sets the limit of height or the possibility of timber exposure, but there are several examples where rules were modified by individual case studies, showing that with the support of tests, the legal framework is not always fundamental. Some countries are dominated by some professionals like architects or timber engineers, others tend to have more heterogeneous professionals. The private or public influence on the case-studies also changes according to the country. Private and public initiatives in favour of building a sustainably emerged as one of the main drivers behind the decision to realise these buildings. But these are not the only reasons and other relevant findings are reported.

Chapter 7 - Conclusion

The last chapter summarises and comments the major findings of the work. Furthermore, it contextualizes the findings and adds them to the body of the academic discussion on MTBs. The context which determines what makes an MTB is really influential in determining the final outcome and every factor (legal framework, political initiative, professionals and timber industry) can have a relevant design influence. Due to these influential factors, MTBs are not similar everywhere. The attention given in this dissertation to the relationships between case-studies and stakeholders, also evidenced that sometimes these relationships can explain why an MTB was built in the way it was built. The chapter ends with proposed guidelines for future work, as with final remarks.

Appendix

The Appendix provides a single-page case-study description of each of the 197 case-studies in which the data gathered in Chapter 4, Chapter 5, and Chapter 6 are displayed all together. In addition to the data, relevant images representing the case-studies are provided.

Chapter 2

Rationale for Building MTBs

Before answering the main research questions, it is worth clarifying the context of the research of this dissertation, and why it makes sense to build with timber in today's environmental situation. Green House Gasses (GHG) are increasing incrementally every year. The literature clearly reports the negative events which will take place as a consequence of high emissions. In addition, the world is becoming more and more urbanized, with people from the countryside pouring into the cities, in search of better opportunities. For the first time in the history of mankind, the majority of people now live in an urban environment rather than a rural one. If cities continue to be built, and to expand with the same construction materials they have been using up to this point, it will be very difficult to mitigate the GHG emissions. The construction sector is one of the largest contributors to the global carbon footprint, with reports showing that buildings are responsible for nearly 40% of annual GHG emissions with 11% of those emissions connected to the embodied carbon associated with building materials alone. If harvested responsibly, timber is a natural carbon sink, because it absorbs more carbon as it grows, and then it releases as carbon dioxide. By utilising timber-based products, the construction sector could avoid the substantial GHG emissions associated with the concrete and steel production process, and would allow the timber elements to continue to store CO_2 throughout the building's life-cycle. Furthermore, the chronically low productivity of the construction sector coupled with the future high demand for new buildings may be other challenges for the reduction of GHG emissions. The valorisation of skilled and aged labour and slow construction time, along with other factors, are considerable challenges both for established and upcoming companies. Prefabrication has been suggested as the best way to increase productivity and timber is perfectly suitable for it, because it is light and easy to work with. In addition to these aspects, several studies have proven that indoor exposure has many health and acoustic advantages which strengthen its position as a valuable constructive material. This chapter explains the context of MTBs, and discusses the academic findings in favour of them. The conclusions in this dissertation will not only show timber as an appropriate material for the construction sector in this century, but will also highlight its other key-properties which make it a valuable alternative material.

2.1 Decarbonisation

The industrial revolution allowed mankind to achieve an unprecedented level of wealth. At the end of the 19th century, Western civilization started to steadily develop at an historic pace. If progress and the new technological developments increased the people's wealth and life quality, they simultaneously caused the rise of the world GHG emissions. As Figure 2.1 shows, in 1950 the main two producers of CO_2 were the United States and the most developed European countries (EU-27). Sixty-eight years later, the amount of CO_2-emitters involves practically the entire globe, with China emitting the majority.

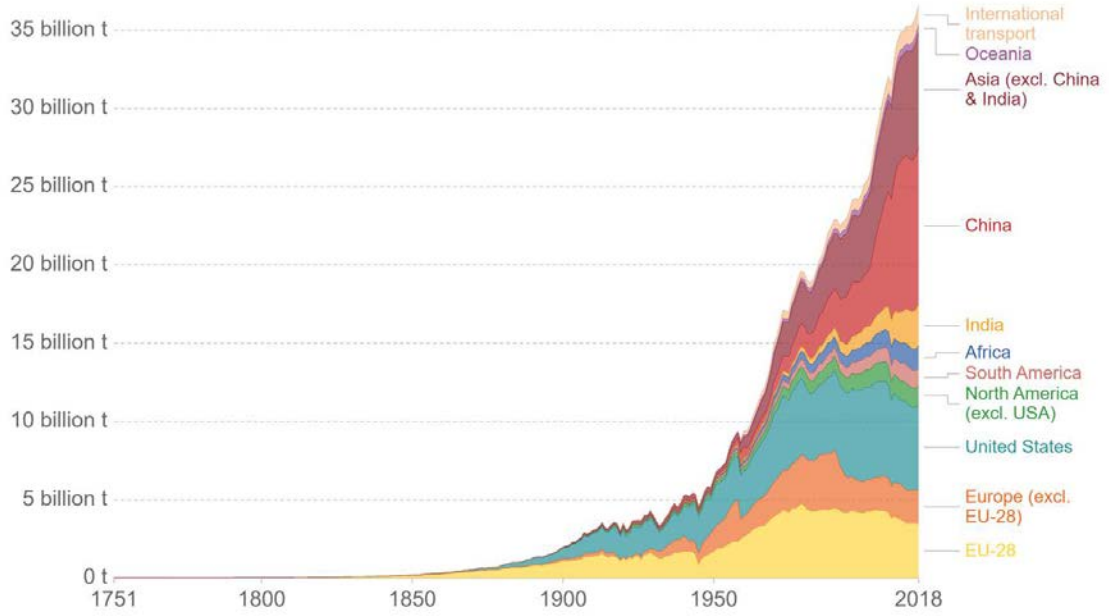

Figure 2.1: Annual total CO_2 emissions, by world regions

Source: Our world in Data, Carbon Dioxide Information Analysis Center (CDIAC), Global Carbon Project (GCP)

Why are GHG emissions an issue for our planet? When wood, coal, or gas is burned, the carbon in these fuels is oxidized to form carbon dioxide (CO_2) which is then released into the atmosphere. Other gases are included in the broader GHG definition: some of them are methane (CO_4) and Nitrous oxide (N_2O). These emissions can be absorbed to some extent by the ocean, chemically combined with rocks, and absorbed as a part of the photosynthesis process. However, all of these processes are not able to keep up with the billions of tons of emissions being released into the atmosphere every year (Arguez et al., 2020). When it accumulates in the atmosphere, CO_2 traps heat radiating both from the Earth's surface and from the sun.

This results in what we know to be global warming, which causes other collateral effects to the equilibrium of the planet which are generally referred to as "Climate Change". The average temperature has risen by about 0.8 °C from the pre-industrial level (Berkeley Earth, 2019). 2016 was the hottest year on record, with 2019 coming in second and 2015 coming in third (Arguez et al.,

2020). If the emissions of GHG continue at their current pace, the Earth's average temperature will rise by at least 1,5 °C above the pre-industrial level by the end of the 21st century (Arguez et al., 2020). This will cause more frequent and more severe heat waves, more floods in wet regions, more droughts in dry regions, heavier storms, hurricanes, and many more problems for mankind (Lugo, 2000) (Ashleyand et al., 2005) (Xu et al., 2009). The worst case scenario would be the rise of sea level from anywhere between 0.7 and 1.2 meters caused by the melting of ice in the poles (Galbraith et al., 2002) (Nerem et al., 2018). A rise of 2 °C is considered the most that the world can adapt to (Masson-Delmotte et al., 2018): Figure 2.2 shows that according to the estimated trends, we are headed towards this scenario.

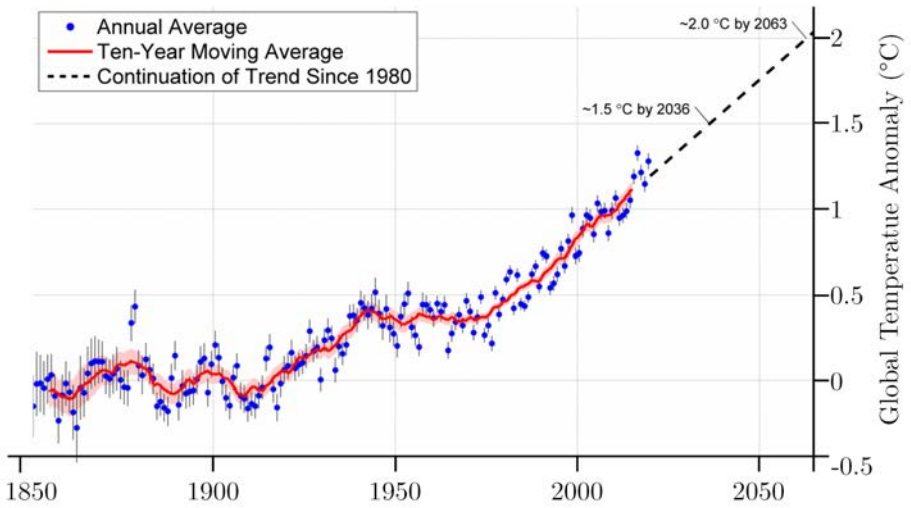

Figure 2.2: Trend of the World's increasing temperature

Source: Berkeley Earth (2019), NASA

In order to keep global temperatures down, GHG emissions have to be reduced by half or more by 2050, and eliminated before the end of 2100 (Masson-Delmotte et al., 2018). In this context, the building sector holds a large portion of the responsibility by generating nearly 40% of the annual global CO_2 emissions: 28% as building operations and 11% as building materials and construction (Architecture2030, 2018). In comparison, cars and transportation global emissions are accountable for around 33% of the global emissions (Green and Karsh, 2012).

Concrete and steel are the main building materials which are used for construction worldwide, especially when it comes to large real estate developments. The production process of these materials alone are account for respectively 4% and 5% of the 40% construction GHG emissions (Green and Taggart, 2017). There are several structural, economical, and social reasons why these buildings are the preferred construction materials to build with. A few of these reasons are briefly described in the next chapter. One way to tackle the building sector's GHG emissions would be to use building materials which can be produced with less energy and therefore emit less CO_2 (Metz et al., 2001) (Mahapatra and Gustavsson, 2008) (Sathre and O'Connor, 2008).

2.2 Forest Management and Timber Life-Cycle

In this context, timber can play a role. With its nearly carbon-free production cycle, timber not only does not produce CO_2 in its production process, it even stores CO_2, making it by far the most sustainable material available today (Sathre and O'Connor, 2008) (Mayo, 2015). Several studies have compared concrete and steel GHG emissions related to their construction process with the standard EWPs. The findings are all in favour of timber (Gustavsson et al., 2006) (Sathre and O'Connor, 2008) (Gustavsson et al., 2014) (Nguyen et al., 2018) (Vihemäki et al., 2019): among building materials, timber not only produces fewer emissions according to life-cycle assessment, but can also store carbon (Vihemäki et al., 2019) (Amiri et al., 2020).

How can timber and forest management tackle the increasing CO_2 emissions? Trees (and forests) are sequestering carbon, thanks to sustainable forest management. However, forests do not constantly and incrementally sequester carbon overtime. After the initial growth, the CO_2 sequestering capacity of a forest arrive to a point in which it reduces the carbon uptake and achieves equilibrium. Additionally, the growing forests produce oxygen. As trees die and rot, they release CO_2 back into the atmosphere. The forest reduces the number of trees in its group, and the remaining trees grow taller and stronger, but in the end effect the carbon balance remains consistent (Cherubini et al., 2011) (Creutzburg et al., 2017) (Vihemäki et al., 2019). This process can be managed and controlled, and this is the advantage of having forest management.

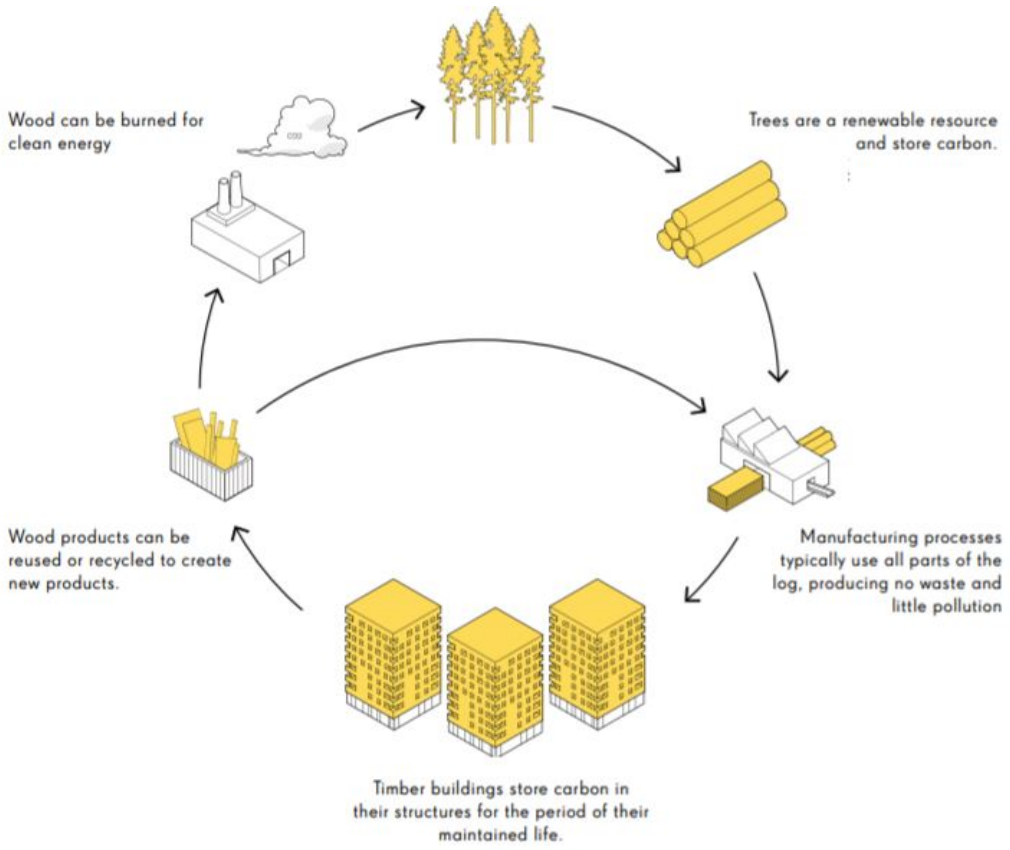

Figure 2.3: Life-cycle of timber construction

Source: Yugon Kim, (Waugh Thistleton Architects, 2018)

By taking timber from a forest and utilising it for carbon-storing goods, such as furniture, the amount of timber which eventually would rot and be released CO_2 back into the atmosphere is actually removed from the forest. This process is even more relevant when the timber taken from the forest is used for construction of buildings, avoiding high CO_2 emissions from alternative concrete or steel structures (Vihemäki et al., 2019). The building will continue to store that amount of CO_2 until the end of its life (Hafner et al., 2012) (Creutzburg et al., 2017). Timber therefore not only can be used as a tool to shrink the CO_2 emissions caused by construction, but by using EWPs products in its buildings, the industry can even store and absorb CO_2 (Lehmann, 2012) (Darby et al., 2013). In this scenario, timber buildings can be seen as carbon storage, and the higher amount of timber they use in their structures, the higher amount of CO_2 is locked into them. This is why trees and forests are a great additional tool for the construction sector. On the other hand, it is important to understand that the benefits of timber in construction are strongly connected to the managed forests from which the timber is coming (Hafner et al., 2012) (Ramage et al., 2017). This is valid particularly for timber sources outside traditional Western countries, where there is a risk of forest depletion (Ramage et al., 2017). Furthermore, in order to have any real climate effect, it is necessary that these timber buildings (or carbon storage goods) possess the captured carbon for a long period of time (Hafner et al., 2012).

Meanwhile, agriculture has made huge improvements, leading to a massive increase in efficiency. In some parts of the world, this led to the conversion of the farmland to temperate forest (Currie and Bergen, 2008), and the number and size of managed forests have been increasing in the past years. Tropical forests are still being cut down, but at much lower rates in comparison to previous centuries (Hänninen et al., 2014). Figure 2.4 shows the positive trend.

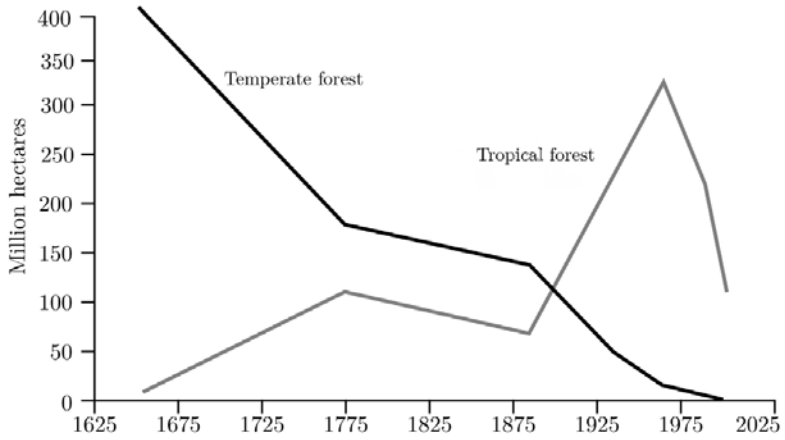

Figure 2.4: Trends in World's deforestation

Source: United Nations Food and Agriculture Organisation 2012

Finally, the potential role of timber in construction is supported by several global implications. Most countries of the world signed the Paris Agreement in 2016, which requires the countries to report and keep track of their emissions (Hulme, 2016). In addition, individual countries developed and implemented regional or national Embodied Carbon Regulations which share the same goals of

the Paris Agreement, reducing the CO_2 emissions in buildings (mainly its Life Cycle Assessment). These programs include the 2000-watt Society and Minergie Eco in Switzerland, the net-zero energy incentives in France, and the English BREAMM. Under these circumstances, it is clear that timber should be used more in the construction sector.

2.3 Urbanisation and Densification

According to the 2014 United Nations Report, there were eight billion people living in the world, and this number is projected to rise to 11 billion by 2100 (United Nations, 2014). Other studies are skeptical, and suggest that the population will peak at around nine billion between 2040 and 2060, and then it will start to decline (Bricker and Ibbitson, 2019) (Lutz, 2019). But while the future population numbers are debatable, everyone agrees on one the existence of another phenomenon which affects the world population: urbanisation.

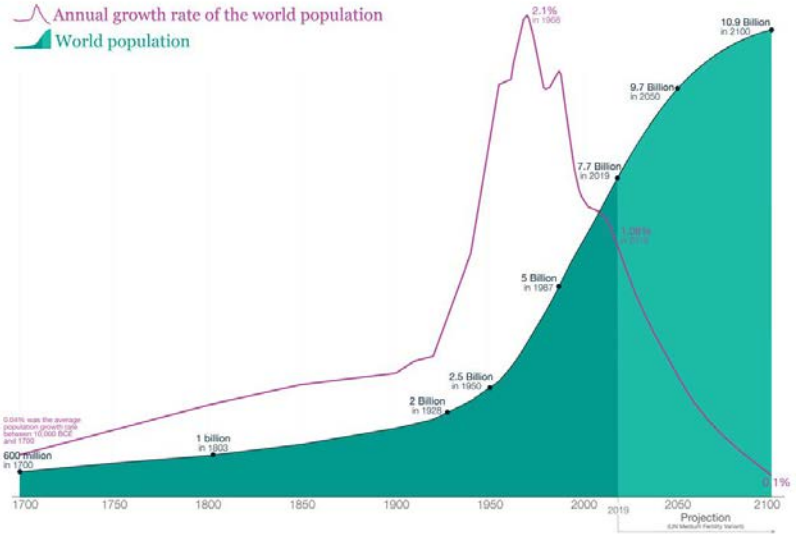

Figure 2.5: Population and population growth 1750-2015 and projections to 2100

Source: Our world in Data, Roser et al. (2013)

Urbanisation is not a new phenomenon in the history of mankind. The inhabitants of the last millennia have depopulated and repopulated the cities due to war and disease. Globally, the population of the world has been, up to this point, mostly rural, with the majority of people living in the country-side. With a high birth rate balanced by a high death rate, the population of the past grew slowly, and were often slowed down by wars and diseases (Bricker and Ibbitson, 2019). Things changed in eighteenth-century Europe (Hartwell, 1961). The Industrial Revolution came to England first, with European countries and the United States coming afterwards. This brought mass urbanisation to cities, an event which was completely new to mankind. The prospect of better standards of living, along with a growing labour demand, and better salaries, induced a large number of people from the countryside to pour into the cities. Villages with a few thousand inhabitants became actual cities, with more than 350,000 people over the course of a few decades.

Manchester being a primary example of this rapid growth (Hartwell, 1961). London in 1860 was the largest city in the world with 3.2 million inhabitants (Bricker and Ibbitson, 2019). All these people needed a place to live, causing mid-rise buildings with several storeys to be built with bricks (and in some cases timber was used in floor slabs) all over Europe and the US. This trend did not change over time. The countries which experienced the effect of the Industrial Revolution (followed by the Second Revolution), saw their cities swell with the constant flow of new-comers.

The growing wealth and improvements in technology, along with the migration of people from the countryside to cities, started to affect other areas in the world. In 1950, only 30% of the world's population lived in urban areas, even if the percentage in the most developed countries was higher. As countries continued to grow in wealth, they also continued to become more urbanised. In 2007, the UN declared that for the first time, in the history of mankind, the world was more urban than rural (Hanlon, 2007). By 2050, it is predicted that 68% of the world population will live in cities (United Nations, 2014). Every day, every region of the planet is becoming more and more urban: the world faces unprecedented rates of urban expansion. And which strategy do cities apply when they become population dense? They build high. Mid-rise and high-rise are the main building typologies that cities use to tackle the rising number of inhabitants.

Urbanisation and density in cities have advantages and disadvantages, they can make the access to essential services easier, and can improve the movement of people thanks to public transportation (if reliable). At the same time, if not properly planned, they can lead to overcrowded schools, poor healthcare, and a higher rate of criminal activity. But densification also has the potential to further tackle the environment situation. Having fewer people in rural areas and more people in cities means fewer people using cars, and fewer households to be heated, which translates to lower CO_2 emissions. More flats in high-rise buildings consume less energy for cooling or warming, and more people using public transportation reduces the quantity of CO_2 emissions.

The potential of multi-storey buildings is not only linked with the clear possibility of reducing CO_2 emissions, it can also lead to another opportunity: reforestation (Bowyer et al., 2016). The amount of farmland in the world is expected to decrease (Ritchie and Roser, 2013). The technological improvements made by the agricultural and chemical industries, along with other economic scenarios, will likely invert the current status, allowing farmland to be turned into land for forests (Bricker and Ibbitson, 2019). More people living in multi-storey buildings use less m^2/per capita, leaving more space free. And if well managed, all these saved square meters could be turned into green areas. More trees in managed forests will mean more CO_2 sequestration. Bricker and Ibbitson (2019) imagines a possible scenario in which more people live in multi-storey buildings in cities, with fewer amounts of land used to produce food and crops and more land which could be turned back to green areas. This seems both possible and necessary in light of the potential CO_2 reduction strategies. Multi-storey buildings made of timber can be a great solution to tackle the challenges of the 21^{st} century.

2.4 Productivity in the Construction Industry

An explanatory definition of construction is given by Mahapatra and Gustavsson (2008): *"Construction is largely a project-based activity where several interdependent subgroups come together temporarily to achieve a task over a specified time"*. The construction sector is one of the largest in the world economy (Barbosa et al., 2017) (Ribeirinho et al., 2020), and from 1945 until 2018 the world has been built 60% of the existing buildings (Ritchie, 2018). However, considering the vast importance and economy related to, the construction industry is often considered as traditional, conservative and slow-to-change sector where technological innovations can take several decades to be implemented (Gann, 1996) (Grübler et al., 1999) (Manseau and Shields, 2005) (Clason, 2007) (Mahapatra and Gustavsson, 2008). This happened according to Mahapatra and Gustavsson (2008): *"due to the characteristics of the industry and also possibly due to path dependence of the existing innovation system resulting from the technological, institutional, economic, and social factors that support the existing system"*. The lack of permanent networks of actors, limits sustained interaction among the actors, which is vital for innovation (Mahapatra and Gustavsson, 2008). Since the same project is rarely repeated and the same group of actors infrequently involved in another project, there is low transfer of knowledge gained from one project to another (Dodgson and Rothwell, 1995) (Reichstein et al., 2005). The low transfer of knowledge hampers innovation.

All these aspects led the construction sector to register a global productivity with nearly 1% growth in the last 25 years, whereas in other sectors like manufacturing or agriculture, has increased considerably (see Figure 2.6). Paradoxically, at the same time, we can observe that parts of the industry are highly industrialised. Some companies can pre-assemble a wide range of elements, from MEP installations, to entire bathroom-boxes. Also the building envelopes can be prefabricated and installed on site with really tight tolerances. Timber and steelwork constructions are especially based on pre-assembled parts, or site assembly.

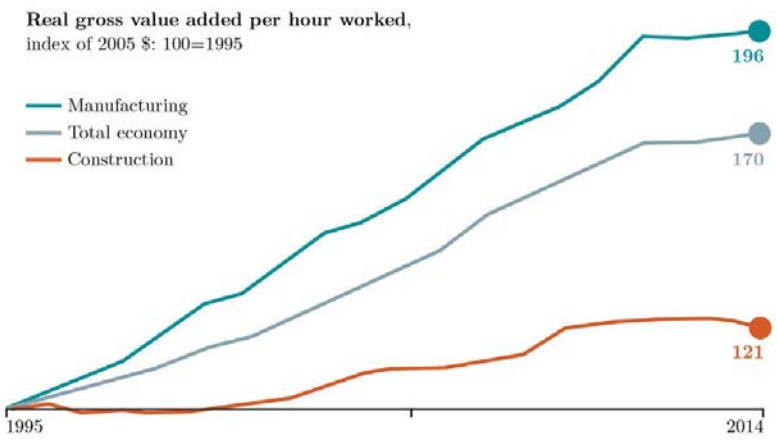

Figure 2.6: Global labor-productivity growth

Source: GGCD-10; national statistical agencies of Turkey, Malaysia, and Singapore; OECD, Rosstat; US Bureau of Economic Affairs; US Bureau of Labor Statistics; WIOD; World Bank; McKinsey Global Institute analysis - Elaborated by the author

However, the coordination between the different building parts suppliers stays generally still challenging, and often rudimentary tools end up to be the final choice of assembly.

It was mainly in the last decades that the limits of the construction sector emerged more vigorously. On one hand, the rise of the Internet and of software developments broadened the differences with the other industries like manufacturing. Innovative software's possibilities like Building Information Modelling (BIM) or automation processes are still far from the norm when it comes to design processes procedures (Clason, 2007). Nowadays, still the minority of building construction companies use BIM software, and even less use the full potentials (5D or 6D). The same is valid for architectural or engineering offices, where 2D software are still widely in use (Aberger, 2017).

On the other hand, the drive to more sustainable buildings led to higher requirement standards of construction. In order to achieve energy certifications or high-performing buildings, were developed more complex construction assemblies and systems. Together with this, attention to details became more and more important, for example in the building envelope, the junction between different structural materials, moisture penetration, etc. The outcome of all these requirements was for some designers and contractors to contemplate prefabrication. Off-site construction is thought to have the potential to increase efficiency, reduce costs and improve quality of construction (Ribeirinho et al., 2020). Johnsson and Meiling (2009) claim that the use of modules may shift 90% of the work from the site into factories. According to Moghadam et al. (2012) *"modular construction and factory production provides opportunities for applying lean principles and thus helps to better manager cost, schedule and project quality"*. This can be achieved thanks to the more predictable workflow inside the off-site facility (Howell and Koskela, 2000), and waste savings (Jensen et al., 2009) (Ruuska and Häkkinen, 2016).

It is in this context that timber construction emerges as a possible way and example to improve productivity throughout its vocation to prefabrication processes (Mahapatra and Gustavsson, 2008) (Aberger, 2017). Correlation between the use of timber in the construction industry and increased productivity are discussed in several studies (Mahapatra and Gustavsson, 2008) (Barbosa et al., 2017). Aberger (2017) observed that timber construction companies and professionals in Austria are more keen to BIM design in comparison with traditional construction companies. The reasons for the higher productivity of timber construction sector, according to Mahapatra and Gustavsson (2008) are *"because production of a timber building is less complex and hence faster than production of, for example, a concrete building"*.

Prefabrication has different grades of assembly. A company can utilise the vertical structural elements (columns, beams) with pre-installed connections, the entire panel element with all the structural and not structural elements already mounted (such as facades or walls), or the entire 3D element (see Figure 2.7). The 3D element can include furniture which has already been assembled.

Figure 2.7: 3D modules' assembly chain at Kaufmann Bausysteme

Source: Götz Wrage, Detail

In this way, the prefabrication process has clear benefits when it comes to construction, some are listed below:

- *Workforce:* the fact that the element is assembled in a warehouse (or protected place), ensures a higher control of the element, it leaves the element protected from weather conditions and allows any type of worker of any age to access the element and safely work on it. In this way warehouses consolidate workforce and machines, while the building site is more dispersed (Howell and Koskela, 2000) (Johnsson and Meiling, 2009) (Ruuska and Häkkinen, 2016). A comfortable and safer environment could trigger new workers or make better use of the existing labour force (Howell and Koskela, 2000). At the same time, due to the new standards of sustainability, the sector will need a more highly skilled labour (Barbosa et al., 2017).

- *Fast:* in a world that is becoming more and more globalized, time aspects became much more relevant. Therefore every way to reduce costs has become important. The best way to reduce costs is to build rapidly. Time of production and construction have become important factors for the building-economy and the increasing speed at which buildings need to be built is a central issue. Prefabrication leads to quicker assemblies, especially if done in series (Ribeirinho et al., 2020). The advantage is that the construction can be faster and more precise. Because of design concepts which require higher design details, once the element is in the construction site, it can be quickly mounted, resulting in buildings being built at a faster pace (Howell and Koskela, 2000) (Moghadam et al., 2012) (Ruuska and Häkkinen, 2016).

- *Accuracy and reliability:* high speed puts high demands on accuracy in the process and this is not easily obtained. Industrialisation is to some extents bound by uniform rules and standards. Standardisation strives to draw lines for a product and its parts making them simpler to obtain in long series. The grade of prefabrication, the environmental process in which these types of buildings are built, the degree to which the elements are standardized, and at what stage the design process is in, all influence the accuracy and detail of the

building's design (Howell and Koskela, 2000) (Moghadam et al., 2012) (Ruuska and Häkkinen, 2016). Thanks to this efficient workflow, the amount of waste on a building site could be reduced (Jensen et al., 2009) (Ruuska and Häkkinen, 2016). The development of new machines and their software, consolidate their key role in prefabrication. The precision degree which CNC can achieve turned the production of the components to precision down to a millimeters degree, opening new possible paths for timber manufacturing. All these aspects can guarantee a better understanding of the assembly on-site and therefore allow the contractors to rely on precise time-schedules of the assembly.

- *Noise and transportation:* by assembling the building parts in an off-site area, the noise emitted by the construction can be drastically reduced in the building-site. Coupled with the high precision of the parts, once in the building site, the pre-assembled elements would just need to be connected to the other elements of the building. Depending on the degree of prefabrication, prefabricated elements are easy to transport, especially if they are lightweight, allowing fewer trips from the warehouse to the building site (Howell and Koskela, 2000) (Ruuska and Häkkinen, 2016).

In light of the challenges presented in the previous section, the construction industry would not only need to reduce its GHG emissions in both the construction processes and the production of its construction materials, but will also need to improve its productivity. Sustainable targets set by some countries, coupled with a long and stagnant productivity growth in the last twenty-five years, and with the present day challenges in housing the influx of people moving to cities created an even harder scenario. A possible answer to this dilemma is the prefabrication of its constructive elements, likely with EWPs, which currently have a certain momentum in the sector due to their suitability for pre-assembly processes, CNC machining, digitalisation, transportation (Hynynen, 2016).

2.5 Benefits of Using Timber Indoors

The previous sections of this chapter underlined the main reasons why timber and MTBs can be appropriate answers to the environmental challenges of this century. Besides the evident properties of a low carbon-emission in production processes, the capability to store CO_2 and the workability and suitability for prefabrication, several studies pointed out another relevant benefit of timber which is its capability, when timber is used in construction, to increase the well-being of people spending time in the building (Lowe, 2020). Positive results were found based on examinations of the health effects of timber as construction material (Yuko et al., 2007) (Jonsson et al., 2008) (Anttonen, 2015). It is worth mentioning that not all the causes have been proven scientifically, but experimental findings support the statement that timber exposure has the feature in health improvement (Lowe, 2020). The list below summarises some main benefits discovered by this type of studies:

- *Humidity Control*: when timber is used as interior building material or as exposed structural element, it creates a healthy indoor climate (Simonson et al., 2001) (Anttonen, 2015). The organic properties of timber add thermal benefits and helps to balance the humidity level inside a building reducing the problems with mould and allergies (Anttonen, 2015). This is possible because wood is a porous material which can absorb moisture when the humidity levels are too high, and it releases moisture when they are too low. In addition, by having a low thermal conductivity, wood feels warmer to the touch (Kuo et al., 2019).

- *Stress reduction*: timber reduces stress when is left exposed, especially in schools and offices (Muilu-Mäkelä et al., 2014) (Kuo et al., 2019) (Lowe, 2020). Some studies showed evidence that exposure to timber surfaces, is correlated to a drop in cortisol, which is the primary hormone liked to negative impacts of stress. Having lower stress levels, students, employees or users have a better productive behaviour (Anttonen, 2015) (Knox and Parry-Husbands, 2018).

- *Warm and preferable material*: from the users' point of view, timber is considered generally warm, comfortable and pleasant to touch and see (Anttonen, 2015) (Lowe, 2020). A Swedish survey of tenants of timber buildings who lived in a concrete building before, reported that the majority (84%) preferred to live in an apartment built in timber (Mahapatra and Gustavsson, 2008).

These few points evidenced that designer could not only use timber to mitigate climate change and increase the productivity of the construction industry: timber is also well-suited for the health of the users (Jonsson et al., 2008) (Lowe, 2020). These advantages are no minor findings in the rise of the global awareness of health indoor environments, and they are valid supporting points to the previous advantages of timber construction.

2.6 Conclusions

This chapter covered in detail the main reasons why timber as EWPs in MTBs should be considered in light of the environmental context. Starting from the global need to reduce CO_2 emissions due to their contribution in raising the earth's average temperature, the chapter proceeded to highlight the representative problem of the building sector that the building sector in this context.

The building sector is responsible for a considerable amount of GHG emissions. This is particularly true for the main construction materials, concrete and steel. Because CO_2 emitted needs not only to be reduced, but also to be removed from the atmosphere, timber and forests represent a valuable alternative to tackle these environmental challenges. Today, timber is the only construction material which can reduce CO_2 emissions through its producing process. Thanks to its natural properties, timber can also remove CO_2 from the atmosphere, while storing it within the construction materials. On the other hand, EWPs can be beneficial if and only if they are

products of sustainable forest management. This is especially true in developing countries, where forests are still being cut down, but at a slower pace than we have seen in the past.

The solutions to mitigate the effects of climate change cross several sectors and do not solely rely on the construction sector. What's clear in the context of the construction sector is that only timber, as EWPs, has the capacity to sequester and store CO_2. This is particularly advantageous when comparing timber with traditional construction materials, and must be considered when looking at the urbanisation of the world. With more people living in cities in the near future (including developing countries), it will be necessary to expand the cities, and build more. In this context MTBs represent a valuable alternative. Trends in construction also show a shift to prefabrication and off-site construction. This has many advantages, and it may be a great way to improve the historically low productivity of the building process. Timber is an excellent material for prefabrication because it's lightweight and easy to work with. Through many practical examples, and with the aid of research, it has been proven that in the context of construction, timber can play an important role.

Social, political and economic factors are accelerating the use of timber. Treaties like the Paris Agreement favour the control of CO_2 and many countries have several strategies to reduce emissions, sometimes directly involving timber solutions. Furthermore, wood exposure in the inside of the buildings have, based on academic researches, positive benefits and is preferred by users. This adds another considerable benefit in the use of timber.

In light of all these considerations, with its many positive environmental and constructive aspects, it is possible to say that timber is good for the environment, for people, for the industry, and for building MTBs. The next chapter will explain how it was possible to propose timber as an alternative constructive material.

Chapter 3

The Historical Development of Timber Construction

The previous chapter made the case for timber in construction and specifically for the potential role that multi-storey timber-based buildings (MTBs) can play. Tall structures with multiple storeys made of timber are complex, and it makes one wonder how it was possible to arrive to the idea to build one. This chapter will therefore focus on the overview of the historical and technological developments which led to the eventual design of MTBs.

There are areas of the world in which timber construction is an established tradition. The craftsmanship and the use of the timber in these areas has changed throughout history and developed on different paths, some of these paths lead to multi-storey timber structures being built even centuries ago. Figure 3.1 shows the historical evolution of the main Western techniques and the relationships between them. With the Industrial Revolution, followed by the World Wars, a change in construction materials took place in Europe and the use of timber as structural material started to decay. Since the end of World War II, the majority of the buildings in Europe were no longer built with timber. However, the development of timber for construction never stopped, and modern timber products continued to be developed. In parallel, academics, architects and engineers continued their research, which allowed the technological development of Engineered Wood Products (EWP) to emerge at the end of the 20^{th} century. EWPs not only allowed the industry to reconsider timber as a possible constructive solution for traditional buildings, but also allowed architects and engineers to imagine completely new structures, and new heights. Thanks to the success of recent EWPs, timber is now considered to be a valuable alternative and a versatile construction material. Furthermore, the production of EWPs quickly became globalised and made the "renaissance" of timber in construction, a worldwide phenomenon.

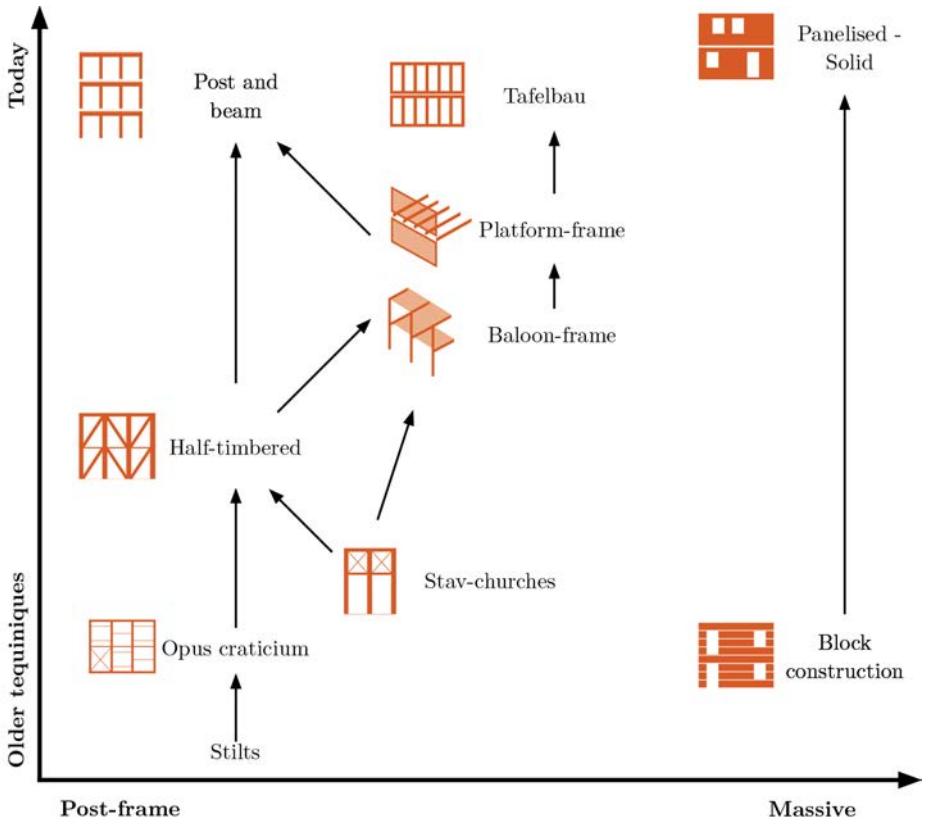

Figure 3.1: Evolution of timber construction

Source: Mehrgeschossiger Holzbau in Osterreich - Holzskelett- und Holzmassivbauweise, proHolz Austria (Hg.), Wien 2002 - Elaborated by the author

3.1 From Antiquity to Industrialisation

For thousands of years, shelters made by early humans were made of trunks and leaves, in order to protect them. In a world full of forests, timber was the easiest solution for construction, thanks to its workability and its abundance (Herzog et al., 2003) (Mayo, 2015). These initial simple structures were made of vertical rod supports of which walls were made by closing the space in-between with clay, other wooden elements, or animal skins. Agricultural advancements allowed mankind to stay in one area, causing civilizations to be less nomadic and more sedentary. This led to these essential shelters to develop into solid houses made out of wood (Kaufmann et al., 2018).

3.1.1 Oldest Techniques and Roman Insulae

Stilts were one of the first types of timber structures which were built from the Neolithic to the Bronze Age, as documented by archaeological discoveries (Herzog et al., 2003) (Zügner, 2013). In order to have an open field for cultivation, the settlers first needed to cut down trees which were then used for building construction. In this way the shores were colonized and stilts guaranteed a strategic position for transport, while also offering protection against dangers and invasions

(Krötsch, n.d.). Early human civilisations adopted timber for their constructions. In Ancient Egypt wood framing was already an established concept and archaeological evidence of timber construction was also found in Ancient Greece (Mayo, 2015).

In Rome, one of the first metropolises of the ancient world, the first examples of MTBs were built (Storey, 2003) (Kist, 2013). Archaeological discoveries found that the so-called "insulae", which were the buildings for the poorer parts of the population, reached from five to eight storeys and their structure was composed of mixed elements, mainly wooden frames, called "opus craticium" (Bottke, 1999) (Kolb, 2002). However, the lack of fire-proof systems like chimneys and water supply, made these buildings extremely dangerous, and collapses or fires were frequent (Bottke, 1999) (Storey, 2003). Vitruvio mentions this technique in his *De Architectura*. He describes its high flammability, admitting as well that its advantage lies in its ability to be quickly constructed (Vitruvio Pollione, n.d.).

Figure 3.2: The House of Opus Craticum, Herculaneum (Italy)

Source: Kuznetsova Yulia

Even if bricks and stone were widely used in the construction of main buildings in the rest of the Roman Empire, timber was still the main construction material. Residential and common buildings were built as block structures (made of horizontally stacked walls stiffened in the corners) or as post structures (designed with beams and columns) staked in the ground (Kaufmann et al., 2018). If block structures were more common in highly forested areas, post structures, thanks to their minimal requirement of wood, were more common in less forested areas. The walls could have been filled with other materials like clay, and did not require high quality wood. However, these structures could not last longer than 20-30 years due to the permanent moisture exposure of the stacked structural elements in the ground. Once the posts damaged beyond repair, the building had to be completely rebuilt (Krötsch, n.d.).

3.1.2 Block Construction and Stave Churches

During the Middle Ages, wooden block construction arrived to guarantee sufficiently stable buildings. These construction methods were known in the Nordic countries as “rod construction” and

in Central Europe as “block-construction.” In rod construction, the wood elements were connected vertically, while in block construction, they were lined up horizontally (Falk, 2005) (Mayo, 2015). Thanks to this system, multi-storey buildings with five or six storeys were not uncommon, and some have resisted even to the present day, such as the block-construction building in Evolène, Switzerland (Winter, 2002) (Kaufmann et al., 2018).

In Scandinavia, an early form of half-timbered was adopted as early as the 11^{th} century. Examples of this technique are the Stave churches[1]. This method used squared wooden frames to form the structural system of the churches, in combination with beams distributed along vertical stands. This combination of beams and stands allowed the forces to run from the vertical stands and then onto the floor (Falk, 2005). At the same time, paying attention to the ground floor connection allowed these churches to resist rotting even today. A testament of this is the Heddal Stave Church in Figure 3.3, completed in the early 13^{th} century (Winter, 2002).

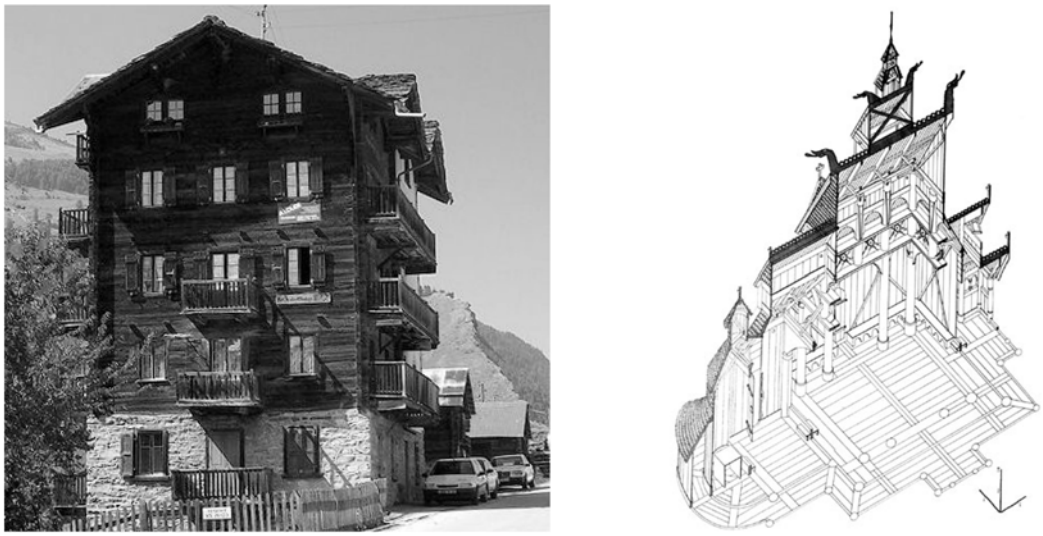

Figure 3.3: Evolène’s blockbau building and Stave Church constructive section

Source: Olivier Bruchez and Jørgen H. Jensenius

3.1.3 Half-Timbered Construction in Central Europe

The introduction in Central Europe of half-timbered construction represented a structural revolution in the use of timber in construction (Kaufmann et al., 2018) (Krötsch, n.d.). Early half-timbered construction was based on the post-and-beam system: the walls consisted of a frame with posts and diagonal beams filled with other materials in the remaining space. Even in ancient times, Southern Europe has been using a similar system (Vitruvio Pollione, n.d.). However, the regions North of the Alps did not see the adoption of the post-and-beam structure until the 12^{th} century. Post-and-beam gradually developed up to and through the 16^{th} century, where it became the main method of construction in Germany. From there, the technique spread throughout all of Europe (Herzog, 2018) (Krötsch, n.d.). The large cross-section of the timber columns and beams allowed

[1]Stave churches’ name derives from the Norwegian *"Stav"* which means "support" or "post"

considerable strength to the elements, and the way they were juxtaposed, allowed cantilevers and different volumes. The detailing for the connection of the elements were made before the timber pieces were mounted in the building site, and this led to the improvement of the carpenters' techniques.

Several aspects favour the development of half-timber construction. The reduction of the European forests and the consequent scarcity of certain types of wood (especially oak) together with the change in carpentry technology led to the need to re-think timber construction (Krötsch, n.d.). Additionally, the advancement of stone and brick construction allowed for a more efficient structural concept (Herzog, 2018) (Kaufmann et al., 2018). The innovations introduced in Germany in the 16th century further improved the system and favoured the construction of even higher multi-storey buildings (Winter, 2002). The established system used vertical uprights from the ground floor until the roof (see Figure 3.4, left) (Zügner, 2013). Individual floors were created by hanging the cross or ceiling beams on stands. The main problem with this system was the higher the house had to be, the higher (and larger) the trunks used for the vertical stand had to be. Additionally, oaks were the preferred tree species and their availability decreased in these centuries (Zügner, 2013). In order to overcome this constructive problem, the vertical stilts were therefore divided by floor and positioned on the top of the one below them. Special joinery and connections were developed to guarantee the transmission of the forces. Large tree trunks were no longer required and from then on buildings with timber posts were possible without natural limits (see Figure 3.4, middle and right).

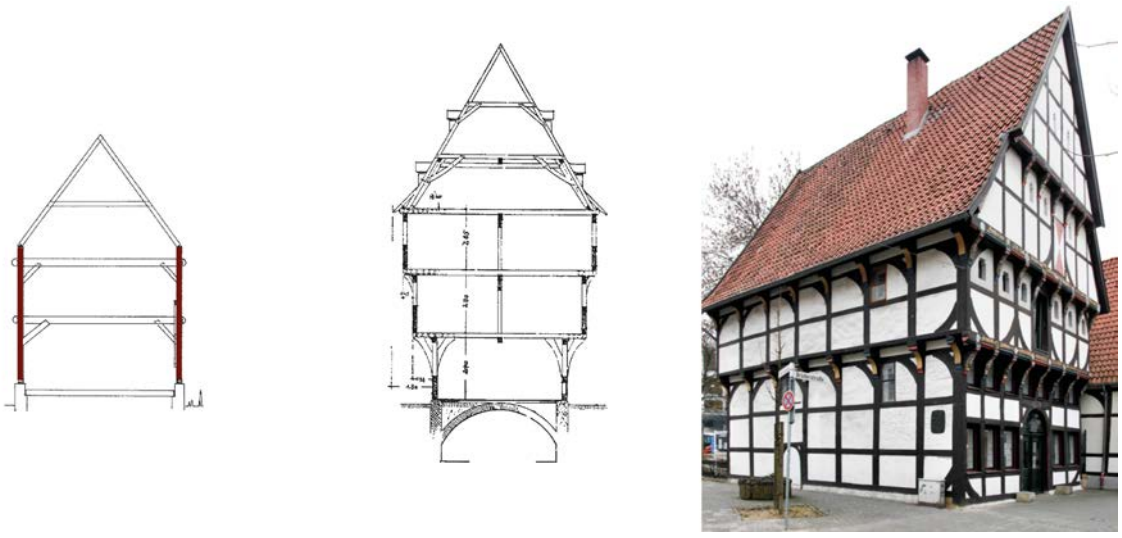

Figure 3.4: Differences between early and late half-timbered construction

Source: Kist (2013) and Thomas Robbin

At the same time, long horizontal trusses were built, thanks to the new carpentry techniques of joinery. This new system favoured prefabrication of the timber elements which made them smaller and more uniform. Prefabrication required planning and designing to be done in advance in order to guarantee the necessary load-bearing capabilities of the structure. The need for advanced planning and design turned the role of the carpenter into a skilled profession (Winter, 2002) (Zügner, 2013).

Finally, this new structure had several other advantages in the construction. By having smaller timber elements, once one was damaged, it could be easily replaced without affecting the entire structure (Winter, 2002).

3.1.4 East Asian Developments

In the meantime, timber construction in East Asia took a different route in their structural development in comparison to Europe. As evidenced by the Hōryū-ji temple (see Figure 3.5), instead of the developing the wall element, the structural principle was the pure timber frame, with the walls of the building having no structural function. In this system, the junction between poles and beams became the key element of the structure, and guaranteed the necessary stability. The multi-layered roof construction had a fundamental structural role, which, thanks to its weight, was to absorb the wind loads (Krötsch, n.d.). With this system the supports are connected to one or more layers of girders, which are then blocked in order to stiffen the building (Krötsch, n.d.). This method guaranteed a certain degree of ductility of the joints, and was also developed to resist the frequent earthquakes, making these buildings earthquake-proof. Many of these buildings are still standing to this day and testify the durability of timber structures.

Figure 3.5: Hōryū-ji temple in Japan and detail of a multi-layered roof

Source: innosho.co and core77.com

3.2 From the Industrialisation to World War II

Industrialization, which started in England and then diffused to the majority of the Western countries, led to major changes, especially for cities. The technical progresses of this age led to new inexpensive construction products, which gradually made timber in Europe obsolete. First came cast iron and steel, followed by bricks and then solid and stable mortar and plaster (Winter, 2002). By the beginning of the 20th century, timber was only used for roofs, ceilings or stairs

in multi-storey residential buildings (Winter, 2002). However, with the development of the mass production of reinforced concrete, timber started to be replaced even in these areas of the buildings. Even with these reductions, timber construction development did not completely disappear, and figures like Otto Hetzer and Konrad Wachsmann kept timber products alive and modernized them for the challenges of the 20th century. In the meantime, motivated by its new territorial expansions, North America industrialized its timber industry, and developed in a completely different direction than Europe.

3.2.1 Otto Hetzer and the Glulam Development

The development of new production technologies and building materials initially displaced timber construction in Europe to some extent in the 19th century and in large parts during the 20th century. While houses in the US and Canada were mainly built in wood, in Europe the traditional wooden houses, especially in the cities, were increasingly replaced by masonry structures (Winter, 2002). Fires were common in the cities. The more crowded they became, the more intense and common the fires were. After large fire damage, such as the Great Fire in London in 1666, authorities started to ban timber in construction (Kist, 2013). Initially, bricks were used principally in the facade of the buildings, meanwhile timber was still used for the floor slabs and roofs. However, by the middle of the 20th century, concrete and steel became established construction materials. The emergence of concrete as alternative material was due mainly to the World Wars which bolstered its production for defence constructions. Therefore, timber disappeared from the material canon both in practice and in the universities (Kaufmann et al., 2018).

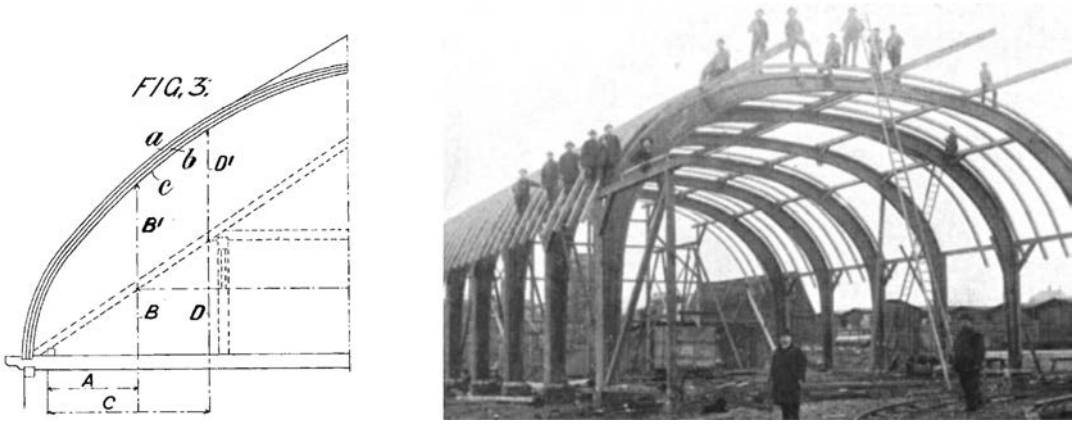

Figure 3.6: Hetzer's patent for a "curved structural timber element" (1906) and Hetzer System - Hall for carpentry, Görlitz, Germany (1910)

Source: Otto Hetzer AG Weimar, Neue Holzbauweisen, Firmenprospekt , Weimar 1912 and Rinke (2015)

In this trend, the carpenter and entrepreneur from Weimar, Otto Hetzer (1846-1911) went against the grain and developed a patent for glued timber boards (Müller, 2004). Attempts to glue boards together were not new, and natural glues like animal blood were used to try to keep them attached (Rug, 2006). Otto Hetzer was alive to see the development of the first car engines, along with the

discovery of gasoline. Thanks to early chemical research, he had access to better adhesives (Rug, 2006). However, by today standards, Hetzer's glue would not be considered waterproof and its structures were mainly designed for dry-construction (Winter, 2002). In 1901 Hetzer obtained a patent for straight beams with several layers bound together with adhesive. He further improved his product and obtained numerous other patents for curved glued laminated beams, becoming the father of modern glue laminated timber, also known as "glulam" (Müller, 2004). In the early decades of the 20^{th} century, the use of glued laminated timber spread gradually throughout Europe. Max Hanisch, a German architect and engineer, emigrated to the United States in 1923 with the expressed intent of promoting Hetzer's glulam construction technology in America. He successfully realized the first modern glulam project in Peshtigo (Wisconsin) displaying the advantages of this new technique in North America (Müller, 2004). The advantages of the Hetzer-system lay in its ability to enable economical construction. The stable and durable timber beams were cheaper than the reinforced concrete competitor and were widely used to build warehouses, halls and bridges (Rug, 2006).

In the late 1930s, many other companies were established, and supplied glue laminated elements for many buildings including churches, halls and factories (Rug, 2006). During World War II, the need for large span elements to cover military buildings, such as aircraft hangars, bolstered the need and interest for the system even more (Winter, 2002). In this context tall timber communication towers were also built in Germany and Poland. For examples, a radio transmitter called "Ismaning" was built in Bavaria (Germany) and reached 156 meters, but was later demolished. The "Gliwice Tower" was also built for the same scope, and reached 111 meters high. The tower is still standing in Poland. At the same time, the aircraft industry needed water-poof adhesive for the planes which were flying throughout the clouds. This also encouraged the chemical research for better, waterproof adhesives. The technical improvements which were obtained during the War, were quickly embedded in the timber industry. In the decades that followed the end of World War II, the mechanisation of the finger-joint technology first and much later computer software and CNC machinery further improved the capability of glue laminated beams and columns, making glulam one of the main EWPs in construction.

Today, glulam is produced all over the world. In Europe, a considerable amount of production is in South Germany and Austria, where the majority of the sawmills are concentrated (Holzkurier, 2020).

3.2.2 Konrad Wachsmann and Modern Timber-Frame

Until the end of World War I the timber construction was still simple and the level of prefabrication was still very low, with most of the components being assembled directly on the building site (Krötsch, n.d.). After World War I, a new system called "panel construction" began to develop in Germany. Originally conceived for barracks for medical usage during World War I, the same system was then used to tackle the shortage of houses caused by the conflict in Germany (Win-

ter, 2002). In 1921, the German company "Deutsche Werkstätte Hellerau", known as a timber furniture manufacturer, presented its first wooden building, which was prefabricated using panel construction (Winter, 2002). The founder Karl Schmidt-Hellerau (1873-1948) was indeed developing a production technique using plywood. Located in the same area, the company "Christoph & Unmack" in Niesky further developed the system and built its factory settlement in panel construction in 1919. When the architect Konrad Wachsmann (1901-1980) arrived to Christoph & Unmack after graduation, the company was already producing serial industrially fabricated timber buildings (Sumi, 2007). Here, Wachsmann developed his interest in rational and standardized construction methods, and he delved in with innovative solutions and details for wooden houses with prefabricated parts in economical and yet varied ways. Afterwards Wachsmann became the chief architect of the company from 1926 to 1929 and led the design of the many houses, including one for Albert Einstein.

Starting from half-timbered construction, Wachsmann simplified the system by standardizing the components and the distances. The technique that resulted, and its assembly can be considered the forerunner of modern panel construction ("tafelbau" in German) (Winter, 2002). Escaping Nazism, Konrad Wachsmann arrived in 1935 in the USA. Here, together with Walter Gropius, he took part in the foundation and management of the first semi-automatic industry for the prefabrication of semi-finished wooden elements for the construction industry called "General Panel Corporation" (Imperiale, 2012). Later he became a design professor and director of the Institute of Technology in Chicago.

Konrad Wachsmann was by far a pioneer of prefabrication and his legacy lies in the importance of timber details as the key for prefabrication. His initial construction system was then developed and improved in the following decades after World War II by the optimization of the material, insulation and cladding, which led to the modern multi-layered panel construction in use today in Central Europe. Tafelbau is composed by vertical sticks and horizontal elements covered with plywood panels (Winter, 2002). In-between the timber elements thermal insulation is placed, and the panels are produced off-site. Only then, they are taken to the construction site.

Figure 3.7: Example of panel construction in Germany

Source: Wolfgang Flamisch

3.2.3 Balloon Frame, Platform Frame and Nail Laminated Timber in North America

In the years of industrialisation there was a great need for a high construction volume in North America. In light of the opening of the West and the need to build railroads, bridges and buildings, the standardization of the construction industry took place by standardizing the elements of construction themselves (Winter, 2002). All these new timber techniques were possible thanks to the invention of nails. Before, timber structures were connected with forged nails with a squared section. Since the 19th century, nails started to be produced in series from an iron wire. This led to cheap nails with which the new American frames and the NLT were connected. On the other hand, thanks to steam-powered sawmills, timber prices went down, and the sawmills were able to supply a higher number of timber boards. This was due to the faster production allowed by new machinery, which led to the birth of the balloon framing construction method. This technique was developed by having boards or wood-based panels nailed to narrow ribs made of standardized cross-sections across several floors (see Figure 3.8).

Figure 3.8: Balloon frame in the US

Source: National Building Museum, Washington

This technique was widely used in North America until it was replaced by its own development, the platform framing construction (or simply frame construction) (Winter, 2002). Frame construction consists of each floor of a pole barn or conventional building being independently framed by nailing the horizontal framing member to the top of the wall studs. The improved technique is still the prevailing construction system in North America, and many multi-storey timber buildings were (and are) built with this system. Due to the vertical studs, balloon framing construction was limited to have two storeys and the timber parts where previously assembled on the ground floor near the building. Only then they were lifted up and connected. With frame construction, the ground floor is completed first. The walls for the first floors are then assembled and erected on top of it, once completed. This is the difference with the European panel construction, which is instead pre-assembled off-site and then transported.

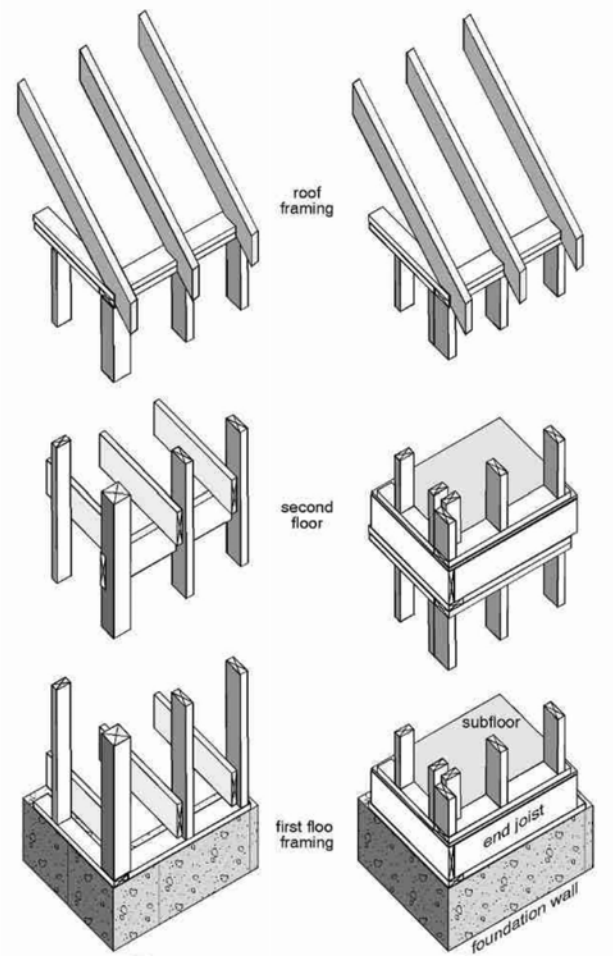

Figure 3.9: Differences between Balloon frames and Platform frames

Source: McGill University

Parallel to the development of the balloon frame and platform frame, the availability of small individual timber members also led to the construction of massive decks formed by boards nailed together (Fourthdoor, n.d.*c*). The so-called Nail Laminated Timber (NLT) consists of vertically oriented sections nailed to each other to form a continuous surface. Initially used in bridges, it was also utilized in building constructions (such as warehouses) for floor decks (Falk, 2005). This technique to build floors remained competitive up to present day, even though glulam became a reasonable alternative in 1960 (Falk, 2005).

3.3 From World War II to Today

Until the end of 21st century, the most significant change in timber construction happened when Cross Laminated Timber (CLT) was introduced to the market (Mayo, 2015) (Kaufmann et al., 2018). The parallel development of Laminated Veneer lumber (LVL) also played an important role, especially in long span timber construction. The so-called "renaissance" of timber, happened when timber tectonics switched from a linear system to a plate system thanks to CLT (and LVL panels) and their innovative production processes (Mayo, 2015). These new EWPs, according to Kaufmann

et al. (2018) *"minimize the inhomogeneity and anisotropy (directional dependency) inherent in wood's fibrous structure and allows high-performance, precisely calculable planar building materials to be made with dimensions that are limited only by manufacturing conditions"*. Together with a global awakening on the environmental effects of GHG emissions on the equilibrium of the planet's climate, along with new amendments to building codes, these materials (and other EWPs) have given stakeholders a wide range of constructive solutions, which were unimaginable even decades before (Bogensberger, 2018). This section describes the development of some major EWPs besides glulam, and gives afterwards an overview of some key-projects which anticipated the realisation of the first five-storey timber-based building, the first case-study in this dissertation.

3.3.1 The Development of Cross Laminated Timber in Central Europe

Today CLT has its origins in Austria and Germany, where the first projects were built (Fourthdoor, n.d.*b*). CLT is the result of the academic theoretical research and the effort of sawmill entrepreneurs to create *"higher value products from side boards"* (Brandner, 2013), which traditionally were not considered to be quality material, or suitable for building. Since the initial stage of the combined research, it took another decade for testing, approvals and distribution before CLT became widely used (Harte, 2017) (Karacabeyli and Gagnon, 2019). In the last 15 years, the product request grew exponentially and by the end of 2018, the only Continent which did not have a CLT producer was Africa (Jauk, 2018).

The idea of producing panels of timber was not a new concept, and there were several products which can be considered forefathers of the CLT idea. In France the designer and architect Jean Prouvé (1901-1984) used the so-called "Panneaux Rosseau"[2] in many projects. The Rousseau panels consisted of three-layers of laminated roof panels and were marketed starting in 1948 for the construction of silos and roofing (Berthier, 2015).

Similar three-layered panels were produced in Central Europe with the German name "Dreischicht-splatte" which can be seen as a forefather of the future CLT. Mainly designed for formwork, these products were used in furniture, facade cladding, and flooring (Falk, 2005). An example of this product was the three-layer wooden panel produced by the Austrian company Doka starting in the 1950s. In these years, Austria built several galleries, retaining walls in the mountains and power plants along the Danube river. The main construction material for these projects was concrete, but there was a need to improve the formworks in which concrete was poured. The company Doka takes the name from the first project in which it was involved, the "Donau-Kraftwerk" (Danube power station) which was founded in order to supply the new three-layered wooden panels necessary to produce the formworks panels necessary for the power station's concrete structure.

In 1995, a Bavarian timber company named Merk, completed a three-storey building in Aichach (Germany) using a cross laminated product called *"Dickholz"* (Thick Timber) (Fourthdoor, n.d.*c*).

[2]The name Rosseau derived from the name of the producer "Rosseau" which marketed the product from 1948 onward.

The building is shown in Figure 3.10. Led by Karl Moser, Merk developed the product in the years before its realisation. To keep the boards together, the company used the vacuum technique, which comes directly from the ship construction. In the same years, Pius Schuler obtained a PhD in 1993 and went on to set up a Swiss company, Pius Schuler AG, where he started the production of three-layered panels called *"BlockHolz"* (BlockTimber) (Fourthdoor, n.d.*c*). The main focus of this product was for residential application.

Figure 3.10: Merk's 1995 three storey project in Aichach

Source: Fourthdoor (n.d.c)

Around the same time the first German success stories began to emerge, the engineer Gerhard Schickhofer in the Austrian Graz University of Technology started his PhD dissertation in 1989. The goal was to investigate the planar behaviour in timber construction. Schickhofer obtained his doctorate in 1994 under the supervision of professor Richard Pichler, who was head of timber engineering at TU Graz (Isopp, 2015) His study was titled *"Elastic analysis of flexibly jointed laminated timber plates"* [3] (Schickhofer, 1994). In his dissertation, Schickhofer applied S. Timoshenko's mechanical theories to multi-layered timber elements, looking at the modulus of elasticity, shear effect and the behaviour of this sandwiched structures (Schickhofer, 1994).

After his completion of the PhD, Schickhofer remained at Graz University of Technology. In 1996, the sawmillers Wolfgang Weirer and Heimo De Monte, founders of KLH, had the idea to improve the use of sideboards as construction material and connected with Graz University. Wolfgang Weier had knowledge of manufacturing machines for sawmills, and he had the idea to create big press machines which could produce three-layers panels. A new research program using Schickhofer's PhD was started and included three sawmills (KLH, Stingl and Santner) along with the Austrian Sawmills Association, which formed a joint-venture between the public and the industry (Fourthdoor, n.d.*c*). With Schickhofer as the head of the R&D program, the goal set by the team was to *"contribute to developing panel systems, which met industrial standards of consistency and regularity"* (Fourthdoor, n.d.*c*).

In an interview, Schickhofer explains the reason why the industry and the academic sector merged

[3] This is the translation of the original German title "Starrer und nachgiebiger Verbund bei geschichteten, flaechenhaften Holzstrukturen"

their interests in the development of CLT: *"The Styrian sawmill industry was looking for possible uses for the sideboards. Fifteen percent of the material from the incision could not really be used optimally. That was the reason to look for solutions. Many were of the opinion that the boards have to be stacked and nailed up. The stacked board constructions were used in Switzerland in particular. We tried that too, but quickly dropped it and turned to the surface, in that we no longer installed the boards standing up, but lying down in the form of glued structures. Cross laminated timber then developed from the project."* (Isopp, 2015).

The first Austrian Government approval was granted one year later, in 1998. KLH started the production site in Katsch (Austria) in 1999 (Kanzian, 2005). Santner successfully started an international supply, and became the supplier to the Norwegian project *Svartlamoen Housing* but went bankrupt some years later. The managing director Helmut Spiehs transferred his knowledge to Binderholz and began directing the CLT production and the product there. In light of the successful development of the material, in the period between 2005 and 2010, other major timber producers like Hasslacher, Mayr-Melnhof and Stora Enso, entered the market, and since then, CLT became an industrial product.

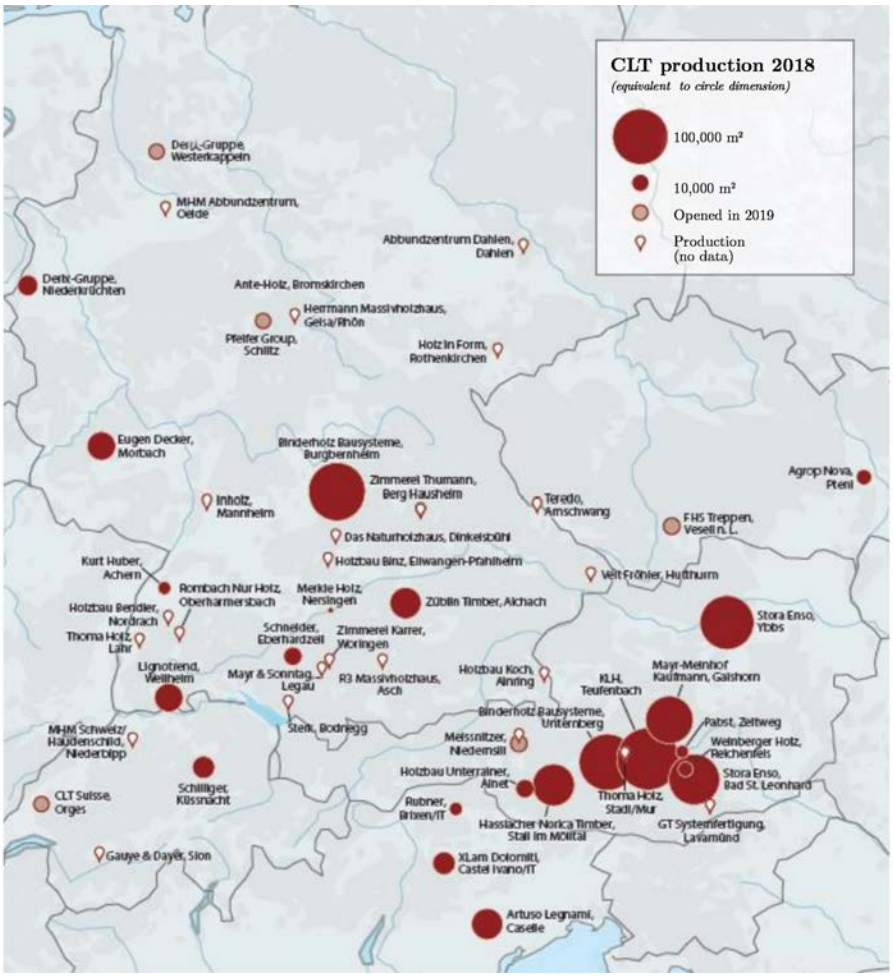

Figure 3.11: Hot spots of CLT production in Europe

Source: Holzkurier (2020)

In the meantime, Merk was bought by Finnforest in 2004 and was later sold to Züblin in 2013, becoming Züblin Timber (Bio-based, 2004). In an interview, Gerhard Schickhofer said *"For me, the first real cross-laminated timber construction in which the large-format surface was visible was the project by Karl Moser and his timber construction company Merk in Aichach. That was 1994/95. For me, Karl Moser was one of the pioneers on the entrepreneurial side."* (Isopp, 2015). If Merk developed the three-layer panels, Schickhofer's research allowed building five-layer panels, which led to new possible solutions, especially for MTBs.

The success of CLT derives from its production process (Mayo, 2015). CLT is a solid wood product that consists of at least three board layers glued at right angles to each other (Schickhofer, 1994). The crosswise gluing creates a material with a panel and plate effect, which can be used as a load-bearing wall, floor slab, and roof. This means that architects can conceptualise the structures made of CLT as monolithic surfaces, similarly to mineral solid construction. There is no surprise that since it was successfully introduced in the Austrian market, the CLT producers grew quickly in Europe first, and later in some other non-European countries. Figure 3.11 shows Europe's hot spots of CLT production. There are several production plants, but the majority (and the one with a higher capacity) are still concentrated in Austria.

3.3.2 Julius Natterer and Dowel Laminated Timber

In 1978, the German timber engineer Julius Natterer became head of the Institute for timber construction (Ibois) at the École Polytechnique Fédérale de Lausanne after years focusing on timber structures. The timber research Natterer did at Ibois covered a wide range of timber systems, applications and combinations with other materials. Particular interest was given to Dowel Laminated Timber (DLT) panels ("Brettstapel" in German), and he is widely considered the father of these panels (Fourthdoor, n.d.*c*).

Figure 3.12: DLT and hybrid testing at Ibois

Source: Sohm Hozbauteknik and Deutsche Zeitung

This system consists of solid timber construction fabricated from softwood timber posts connected with hardwood timber dowels. The advantage of this method is that it does not use glues or nails. Additionally, a part of Natterer's research was focused on hybrid timber-concrete combinations. These combinations were used in Germany in the years after the World Wars due to the lack of building material. Natterer studied connections, combinations and tested several hybrid floor slabs. The findings and results, became the basis for further research across the world (Falk, 2005).

3.3.3 The Spread of Laminated Veneer Lumber from North America

While CLT was developed mainly in Central Europe, Laminated Veneer Lumber (LVL) was originating in the US. LVL is made up of three-millimetres thick veneers bonded together with weather-resistant phenolic adhesive (Federation of the Finnish Woodworking Industries, 2019). The first similar applications of parallel oriented plywood products were initially used in the American furniture industry at the beginning of the 20th century (Federation of the Finnish Woodworking Industries, 2019). The technique of gluing veneer sheets was already applied in the US in 1944 for manufacturing aircraft components (Luxford, 1944) (Kairi, 2005). In 1950 S. Preston found that by using thinner veneers the strength of the timber beam could be improved (Preston, 1950). Finally, in the 1970s Peter Koch and the USDA Forest Laboratory initiated the research on veneer-based wooden beams. Kairi (2005) describes the research findings: *"Koch demonstrated that the mean strength values of beams glued from 4.2 mm (1/6-inch) thick rotary-cut southern pine veneers were significantly better than the values of solid timber."*. Later, the company Weyerhaeuser was able to first commercialise the first LVL product in the American continent.

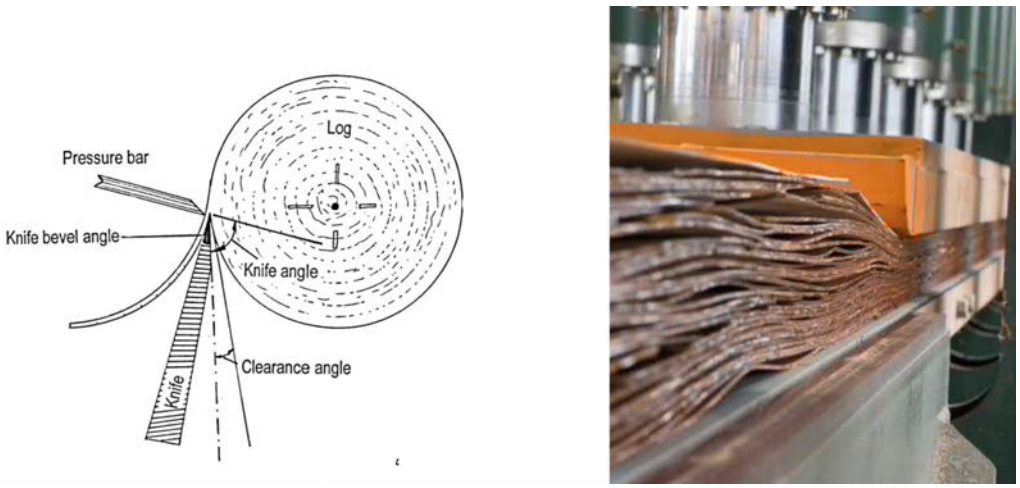

Figure 3.13: Rotary peeling veneer production and pre-pressing

Source: extension.okstate.edu and Federation of the Finnish Woodworking Industries (2019)

At the same time, the Finnish company Metsäliiton Teollisuus Oy (Metsä Wood), was the first European company which invested in this new product by developing its own manufacturing production. This process was further developed by the Finnish company "Raute Oyj" which became a leading company in LVL machinery (Kairi, 2005). In the last two decades of 2000, LVL manu-

facturing and production capacity grew considerably, and today there are several companies over four different continents, with at least 30 production plants which can supply LVL beams. North America is still the main LVL producer, with Scandinavia, New Zealand, Australia and Japan as other main producers besides Northern Europe and Germany.

The success of LVL is also due to its production process. By having multiple three-millimetres thin layers of veneer, LVL is not limited by the dimensions of the raw material. Additionally, the peeling process removes any natural defects such as knots, giving to the timber element homogeneous structural behaviour properties.

3.3.4 Pioneering Projects in Austria and Sweden

By the end of the 20$^{\text{th}}$ century, the timber frame construction method was an established system for multi-storey timber residential construction in North America and in Scandinavia, along with low-rise buildings in Central Europe. In contrast to North America and Scandinavia, Central Europe's construction with timber was still severely restricted by the regulatory framework, mainly due to fire protection regulations. The first modern multi-storey timber buildings were built in the 1990s, with a maximum of three floors (Kaufmann et al., 2018). However, thanks to the commitment of the individual initiatives of architects and timber stakeholders, along with the research done through universities, taller pilot projects started to be realised using timber frame systems in Central Europe, mainly in Austria, Bavaria and Switzerland. It is worth mentioning that in the first modern examples, CLT was not always used, and these first buildings were more of a hybrid timber-based combination, mainly featuring glulam-based products.

The architect Hermann Kaufmann is considered to be one of the pioneers of prefabrication in timber, especially when it comes to design and technology (Zügner, 2013). Growing up in the Voralberg region of Austria, he further developed the particular timber construction culture in the region, which is characterised by an amalgamation of innovation and traditional craftsmanship (Dangel, 2009).

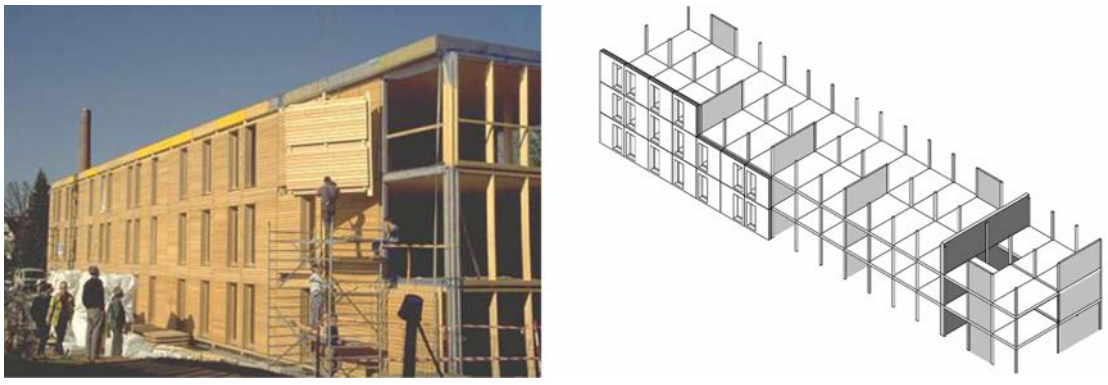

Figure 3.14: *Ölzbündt* construction and its structural system

Source: Ignacio Martinez and Hermann Kaufmann + Partner

Completed in 1997, the residential complex *Ölzbündt* is an example of Kaufmann's design approach (see Figure 3.14). Built in Dornbirn, located in the Austrian region Voralberg, *Ölzbündt* is a three-storey post-and-beam structure with high prefabricated elements, which were ready to be built in order to meet the tight construction schedule. The structure of *Ölzbündt* integrates some concrete wall-inserts which helps divide the building into different fire zones and are also used to stabilize the building (Lattke and Lehmann, 2007). *Ölzbündt* is also one of the first passive house standard buildings in Europe (Lattke and Lehmann, 2007). The tendency to prefabricate the elements and streamline systems in order to build with timber or hybrid combinations is a typical approach of Kaufmann, which will be further explored in later projects in the survey portion of this dissertation.

During the same time period, in another Austrian region, in Styria, residential housing was being promoted by the Housing Promotion Act and a corresponding amendment to the building regulations (Building Act 1995) was approved. This made it possible to build low-rise timber-based buildings in the region. In this context, another Austrian architect, Hubert Rieß, played a pioneering role. Thanks to his expertise in the modern timber construction, he was involved in the early 1990s, in the Bavarian model project "Rental apartments in wood system construction" [4] which had the goal of promoting the Bavarian timber industry (Bogensberger, 2018). This project caught the attention of Styria's timber industry which began promoting timber throughout the Region at the end of the 1990s (Bogensberger, 2018). In 1996 Rieß designed one of the first multi-storey timber structures in Gaishorn, Upper Styria and in 1998 another low-rise residential project was completed in Judenburg (see Figure 3.15), characterised by a panel construction structure above a concrete ground floor (Zügner, 2013). It was the project *Frauengasse I&II* (see Figure 3.15) which was completed in 2002 in Judenburg (Styria) that marked a milestone in the modern timber construction. The building is the first four-storey building ever built, with all load-bearing components, and walls and ceilings made of CLT. With the *Frauengasse* project, it became clear that CLT was ideal for the construction of MTBs thanks to its load-bearing capability and its ease of construction.

Figure 3.15: *Judenburg* and *Frauengasse I&II* projects

Source: Damir Fabijanić and Manfred Seidl

[4] Translated from German: "Mietwohnungen in Holzsystembauweise".

From this point, once the rules were relaxed for timber, CLT began to gain importance in timber construction and the number of CLT buildings grew significantly (Zügner, 2013) (Kaufmann et al., 2018). In 2001, the technical requirements in the city of Vienna were changed, and allowed buildings with up to four storeys to have a timber structure (Kaufmann et al., 2018). This was the necessary catalyst which allowed the realisation of the first five-storey timber-based building (four-storey above a concrete ground floor) *Spöttlgasse* which is the first building considered in this dissertation's survey.

In contrast to Austria, the building regulations in Sweden in 1994 allowed buildings with six to eight-storeys to have a timber structure (Falk, 2005). In this context, many research programs led to the construction of light-frame timber multi-family houses of four to five storeys. Some of them, integrated new EWPs which started to enter the Swedish market t the end of the 20^{th} century and the beginning of the 21^{st}. From 1993 to 2000 the first phase of the "Nordic Wood Program" ran as a joint-venture between research institutes, universities, companies and trade associations. The program favoured the realisation of dozens of projects including the residential project *Wälludden* (see Figure 3.16) in 1996. Built in Växjö, this project was the first five-storey timber-framed building in Sweden (Falk, 2005). The realisation of *Wälludden* was a breakthrough for the fire-safety in Sweden and initiated a city interest in timber buildings. This led Växjö to have one of the highest concentrations of modern multi-storey timber-based buildings (Johansson and Schauerte, 2015). The Nordic Wood Programme also had a second phase which promoted even more MTBs in Sweden, like the three-storey *Vetenskapsstaden I* (see Figure 3.16) and *Vetenskapsstaden II* (Falk, 2005). These first buildings demonstrated the new potential of timber and were followed by other timber-based buildings which will be discussed later in this dissertation.

Figure 3.16: *Wälludden* and *Vetenskapsstaden I*

Source: rm.se and (Falk, 2005)

3.4 Conclusions

In this chapter the main steps were outlined which led to the realisation of the first MTBs. Timber construction in multi-storey buildings has a long history of development, some of which has made it possible to in the past to achieve high structures with timber. However, the real changes came thanks to the successful development of some EWPs like glulam, CLT and LVL. These new products appeared thanks to the ingenuity of specific people, together with improvements to the industrialisation processes. In the last years, the collaboration between industry and the public (represented by the university) made the necessary improvement to some EWPs possible.

As described in the previous section, MTBs of three and four-storeys began to be built at the end of 20^{th} and beginning of the 2000s. In the beginning, they were considered a new and niche type of construction. These first buildings constitute the necessary bulk of main technical references to the generations to follow which will go on to have many more storeys than their predecessors, and will be analysed in this dissertation. Chapter 3 showed that timber and multi-storey buildings are not a new combination in the history of mankind. High timber structures were already existing in the past and structures taller than what we have built today, had already been realised. With the start of the 1800s, this tendency changed.

As stated by Kaufmann et al. (2018) *"(...) the switch to a planar structure approach, determined that the joints are simpler, it was possible to make energy efficient envelopes and made them more economically competitive"*.

The first generation of projects identified in the last section of this chapter made possible to develop the necessary initial techniques and knowledge which allowed Austria to build one of the first five-storey examples and initiate the second generation of buildings. The twenty-four-storey *HoHo Wien* or the 85 meters tall *Mjøstårnet* did not come thanks to sudden technological discoveries, neither were they the result of a quick product development. The knowledge which led these buildings to be realised, was derived from two centuries of EWP development and practice.

Chapter 4

Selection of the Case-Studies

Having understood in Chapter 2 why building MTBs is necessary, Chapter 3 highlighted the main historical and technological events which led to the opportunities to build them. The same chapter showed that most of the EWPs used in timber buildings today are relatively recent products, some of which have only been on the market since the early 2000s.

After discussing these introductory chapters, the main part of this dissertation begins. Chapter 4 is composed of three main sections: literature review, survey methodology and a first look at the selected case-studies. Having understood that the best way to answer the research questions is by doing a comparative survey on MTBs, the first section analyses the existing literature. The survey methodology section defines the criteria applied for the selection of the case-studies, starting with the information gathered from the literature analysis. The goal of the survey is to define as many case-studies as possible in order to make a valuable comparison of the current state of MTBs. The intent was not to create a chart of the best-performing countries, but rather gain the best overview of the past and current MTB practices worldwide. The last section within the chapter concludes with the list of the selected 197 case-studies. This list already provides us with a bit of data and answers to the research questions, where and when MTBs were built. Additionally, each project has a reference page in the Appendix where a one-page description has been dedicated to each project. The list displayed here will be further analysed in Chapter 5 and Chapter 6. The analysis of the completion date and the location of the case-studies already shows some geographical differences and evidence that MTBs are a recent typology, and not heterogeneously distributed throughout each country.

4.1 Literature Review of the Comparative Studies of MTBs

There have been numerous publications related to MTBs, however, few comparative studies have been made. The goal of this first section is therefore to analyse the existing literature on comparative studies. Through this analysis, it was possible to learn valuable lessons in order to make the dissertation's survey more inclusive and descriptive.

As also described in Chapter 3, modern MTBs started being built in the late 1990s and in the first years of 2000 (Lattke and Lehmann, 2007) (Falk, 2005). Starting from 2012, as Table 4.1 shows, more and more buildings were completed and some first comparative surveys were made, mainly with an informative scope[1] (Lehmann, 2012) (Holt and Wardle, 2014) (Smith et al., 2015). Once several other dozens of built or planned projects were realised or announced, other studies were consequently made, including therefore a higher number of case-studies (CTBUH Journal, 2017) (Salvadori, 2017) (Kuzmanovska et al., 2018) (Wiegand, 2019). All these studies had an international base of case-studies and their goal was to display quantitative and/or qualitative data of built and planned projects. These studies were used as the starting point in the definition of the list of case-studies which was built in this dissertation and as guidelines for the criteria to use in the dissertation's survey.

Table 4.1: List of main surveys and comparative studies

Study *(author, year)*	**Case-studies** *(number)*	**Status** *(category)*	**Minimum height-threshold** *(storeys or meters)*
Lehmann (2012)	8	Built	Four-storey
Holt and Wardle (2014)	10	Built	Five-storey
Smith et al. (2015)	18	Built	None
CTBUH Journal (2017)	49	Built and planned	Seven-storey
Salvadori (2017)	40	Built and planned	22 meters
Kuzmanovska et al. (2018)	46	Built and planned	25 meters
Wiegand (2019)	49	Built and planned	Seven-storey

Lehmann (2012) makes a comparative study of eight built projects. The goal of the paper was focused on the viability of MTBs in Australia and the study also includes other related topics such as the state of the timber industry, economical aspects and professional involvement. The conclusion of the analysis, which focused on the lack of quality in the Australian housing market, proposes some possible options for the Australian authorities to consider in order to build and prepare the ground for MTBs in Australia.

Holt and Wardle (2014) produced for the office Perkins+Will this is the first global report on completed timber buildings, and even included some multi-storey buildings. This work was commissioned by the Forestry Investment Innovations and BLSC. The goal of the report was to *"(...)*

[1] As shown later on, the amount of completed case-studies per year grew incrementally starting in 2011.

to learn from individual experiences, solutions and challenges, but also from aggregated information". The report consists of ten case-studies described by qualitative information from four specific stakeholder groups: owner/developers, design teams, construction teams and authorities with jurisdiction.

Smith et al. (2015) consists of a report called *"Solid Timber Construction"* whose goal was to focus on the knowledge of "solid wood construction" in the American market. By observing the lack *"a standardized method for collecting data on Solid Timber Construction projects in order to build an empirically evidenced argument"*, the report attempts to remedy this with quantitative and qualitative analyses of eighteen case-studies. The report provides comparative charts, graphs and qualitative descriptions of different case-study typologies and compares several characteristics such as building footprint, height and cost. This report does not specifically considers MTBs, but includes several well known solid wood projects with no specific height threshold.

CTBUH Journal (2017) listed for the first time forty-nine built and proposed "tall timber" projects in the world according to a set of structural and height criteria based on Foster et al. (2017). The list was published in the Journal of the Council on Tall Buildings and Urban Habitat, which is an organisation whose goal (among others) is to promote and share information regarding tall buildings worldwide. The list displays general quantitative and qualitative data of selected case-studies, indicating for example the geographical location and the type of structure.

In his Master thesis, Salvadori (2017) made a survey of forty built and planned projects taller than 22 meters. The projects were analysed in order to give an overview of the actual design possibilities for building a twenty-two-storey timber-based building that is developed in the second part of the thesis. The survey analyses several quantitative and qualitative data sets of the case-studies. In a general section, information such as name, completed year, country, city, height, built square meters and stakeholders involved was provided. In a design section, specifics such as the material of the core, the lateral and gravity load resisting system strategy and fire strategy were also described in a comparative chart. The goal of the thesis was to make the case for using MTBs by providing a list of built examples as a possible alternative to concrete competition projects.

By observing the lack of *"an overview of the wider market context"*, Kuzmanovska et al. (2018) wanted to use a comparative survey to describe the trends in "tall timber construction" under the analysis of three specific lenses: structural, envelope, and architectural. Thanks to its qualitative analysis, this conference paper displays the trends of mass timber construction using forty-six built and planned case-studies. Another concern of this study was to display the architectural variety in the case-studies.

Lastly, Wiegand (2019) analyses forty-nine built and planned case-studies following the same CTBUH structural systems analysis and displays graphically some comparative charts. The intent of the Master Thesis was *"to understand how policy instruments have been effective in promoting the development of Tall Wood Buildings"*, but the research also made a significant contribution in offering an alternative way to categorize these buildings by providing a list of actualised case-studies.

4.1.1 Lessons Learned from the Literature Review

The literature on comparative studies is scarce and not homogeneous as shown in Table 4.1. The different goals of the analysed surveys led to different considerations of the case-studies. For example, when the survey was more practical, only built case-studies were considered, but when the survey was more academic, planned case-studies were also considered. Additionally, the height threshold of the case-studies varied according to the goal of the study. When the study aimed at displaying the current status of mass timber construction, the surveys also included low-rise buildings. If the survey was specifically for MTBs, then a higher threshold was introduced. From the previous literature analysis and comments, it is possible to collect some general feedback which are reported below:

1. **Number of case-studies:** the highest numbers of case-studies surveyed varies between 40 to 50 projects. In order to make a comprehensive study which gives the proper state of the art of multi-storey timber-based construction, the number of considered case-studies should include at least several examples per country (if the comparative study wants to be geographically-based).

2. **Construction Status:** in the most recent surveys, planned examples are often considered. These buildings are announced by the developer or architect, but are not always actually built. An example of this is provided by the American project *Framework* which was announced and designed, but at the very end was stopped *"due to challenges raising enough money to construct the building by the city council"*(Basalyga, 2020). Because the goal of this study is to give a precise picture of the state of the art of MTBs, only built projects have been considered.

3. **Height threshold:** as Table 4.1 displays, the different height-threshold set in the surveys varies from study to study. By observing the last survey's threshold, it appears that a survey which included mid-rise buildings (from five to seven storeys) had yet to be done. So, the literature lacks an analysis of these buildings. Furthermore, 22 meters or a seven-storey height-limit, excludes key-projects which were built before taller examples. This particular aspect was considered relevant in the understanding of the development and practice of the design of MTBs and therefore the height threshold had to be lowered. Section 4.2.1 will cover this in more detail.

4. **Stakeholders:** the role of stakeholders was investigated in very few studies. They were analysed in light of their influence in policies and R&D programs, like in Wiegand (2019), or interviewed to understand the influences and the lessons they learned (Holt and Wardle, 2014). However, no dedicated analysis was ever made on the role of these stakeholders in the realisation of MTBs, their repetition in projects, or on their transfer of knowledge. These particular aspects are missing not only in the survey studies of the literature, but also in the academic discussion in general (Vihemäki et al., 2019). An updated descriptive catalogue of all MTBs' stakeholders is therefore missing and necessary.

5. **Comparative analysis:** only a few studies attempted to compare and analyse other design aspects besides the structure of MTBs in a survey. In order to understand the state of the art of MTBs, and answer the main research questions, a simple structural analysis would be too narrow. Additional design aspects therefore need to be analysed.

The main observation derived from the analysis of the literature, was that the overview of the state of the art for built mid-rise MTBs, along with a comparative study of the stakeholders, was missing. A comprehensive comparative study of both mid-rise and high-rise buildings, and their stakeholders will therefore enrich the current academic and professional discourse. Kuzmanovska et al. (2018) and Wiegand (2019) too indicated the need of a broader base of case-studies and their key-players for future researches. If the first surveys were limited by having few existing built cases, the most recent surveys have shown that there are dozens of built projects, which provide ample material to analyse in a survey. However, the height threshold limited the outcome of these surveys to mainly high-rises leaving out a considerable number of mid-rise projects from the academic analysis. The next section will explain the survey methodology which sets the criteria for building a more inclusive survey.

4.2 Survey Methodology for the Selection of the Case-studies

Through the categorization and comparison of the main design and contextual properties of the case-studies, this dissertation has been organised in the form of a comparative survey, examining 197 globally realised buildings from 2004 to 2019. Additionally, in order to answer the research questions, this survey provides both quantitative and qualitative data on the case-studies.

This section explains the main survey criteria. Once the survey criteria have been presented and set, they were applied to the data sources listed in Section 1.3.2. In addition to the initial body of case-studies already treated by the surveys and other academic papers, other sources were analysed in order to select more case-studies. These sources included online databases, websites of stakeholders, online newspapers and media articles. Through these additional sources, a sufficient number of case-studies was selected. Following the selection, the qualitative and quantitative collections of each case-study data began. In some cases, when data was not found or incongruity appeared, some stakeholders were contacted by email by the author.

4.2.1 Definition of the Height Criteria for the Survey

As briefly mentioned in Section 1.1.2, the literature does not clearly define what minimum requirements need to be met in order to be considered an MTB. The same issue is also evident in the survey literature. Some of the first comparative studies (Falk, 2005) (Lattke and Lehmann, 2007) consider three-storey buildings because at the time, they were some of the highest examples. The first surveys also had a low minimum height threshold (Lehmann, 2012) (Holt and Wardle,

2014), whereas Smith et al. (2015) had no minimum height. The last surveys were, as previously mentioned, focused on high-rise examples, and started from a height of seven-storeys (or 22 meters) (CTBUH Journal, 2017) (Salvadori, 2017) (Kuzmanovska et al., 2018) (Wiegand, 2019). The reason for these recent height thresholds were, most of the time, related to the local height threshold of high-rises according to regulatory framework (Salvadori, 2017) (Kuzmanovska et al., 2018) (Wiegand, 2019).

The threshold of these last surveys was too high to have a clear understanding of the most common mid-rise MTBs. Therefore this survey includes all mid-rise case-studies found in the data sources taller than four-storeys (four-storey buildings were not included). Thanks to this storey-threshold this study can include a higher number of case-studies in comparison with previous studies.

4.2.2 Definition of the Time Period for the Survey

The technological evolution which led to the possibility to realise MTBs was explained in Chapter 3. In the same chapter, the first three-storey examples were also discussed briefly, as well as the first four-storey project *Frauengasse I&II*, which was completed in Austria in 2002.

Given the height-threshold criteria, the survey begins in 2004, with *Spöttlgasse*, the first five-storey timber-based building ever built. The survey research was concluded at the end of 2019, describing the built projects of the last 15 years of construction. Buildings which were not yet completed, meaning that the inhabitants or users were not able to move in or work, were not considered. Sometimes it was not clear if the declared date by the construction (or timber construction) company's website was the effective one. This is usually because they report the day that their specific part in the process was completed, or their parts were delivered, and not when the entire building was usable. Because the goal of this dissertation was to be finished in 2021, the author decided that a cut-off of 2020 would not have been enough time to properly gather and assess all the data from the projects completed in 2020, especially for the projects which were realized at the end of 2020.

4.2.3 Limitations and Omissions

The goal of this survey was to include as many documented case-studies as possible for each country, in order to determine the representative design and contextual properties. Even though the creation of the list was labor-intensive, and the market thoroughly searched for years, it is still possible that this list is not an entirely representative sample of the state of the art of MTBs. From this dissertation, it is possible to understand which countries, in the duration of the time period researched, built most of the relevant case-studies. However, the intention of this work is not to determine the best country for the construction of MTBs. This is due to the omission of many low-rise buildings, and not having considered light frame, timber-framed and similar structures which are typical in several regions of the world.

The definition of what makes an MTB (see Section 1.1) required that many hybrid projects in which EWPs were used, were omitted. This would be the case for the project *Rundeskogen*, in which the main structure is made of concrete, and the interior walls are made of CLT (dRMM, 2012). On the other hand the height criteria based on number of storeys and not meters, left out several projects like the *Sky Headquarter* in London, a three-storey timber building, taller than many five-storeys in the case-study list (Arup, n.d.). The choice of the storey-height criteria instead of a meters-high criteria is due to feasibility. Exact data on the height in meters (or feet) of the majority of the projects was seldom available. It was therefore easier to understand how many storeys a built building had, instead of the exact height in meters.

The methodology adopted has its own limitations. Data available in academic publications are correct in most of the cases, whereas data gathered from other sources such as the internet and other grey literature sources might not be agreed by all the stakeholders. This was true in case-studies where the exact height or total square meters built were reported differently among several websites. Other times, the specific role of some players was also not always clear. In both these cases, the author proceeded with the triangulation of the sources if possible, or by selecting the data from the professionals' website, when no other sources were available.

Some buildings were not listed because of the lack of the information regarding essential design properties and constructive solutions. For examples, two case-studies were found in Japan, both six-storeys high but no complete data have been found. The absence of relevant case-studies from Japan is due to the strict fire regulations in the country which limited the timber structural design in tall projects. But Japan is still a reference point when it comes to timber construction, and many solid timber projects were realised (in Japan and in other countries) by Japanese architects like Kengo Kuma and Shigeru Ban. The latter designed also two case-studies of this survey. The interest in MTBs in the country is growing, so much so, that for example the timber producer Sumitomo Company disclosed in 2019 its plan to built in 2041 a 350 meters skyscraper (Lynch, 2018).

Many MTBs were built in several European countries by the company Moxy Hotels, but no complete information was found. Their height varies across the countries, but some projects reached also eight storeys. Moxy is a company created by Vastint Hospitality, a multinational construction company which belongs to the IKEA and Marriott International group (Kavaliauskas, 2017) (Vastint, 2020). The group is based out of Europe and has initiated a series of co-operations with other general contractors to build the Moxy Hotels. The patent for the Moxy Hotels is own by Vastint Hospitality which developed it with the Italian company Wood Beton (Spatti, 2019). The assembly concept is based on the combination of CLT and concrete.

All told, the goal of this work is to set a body of reference which other researches could benefit from. The challenge presented when including such a high number of case-studies has led to simplifications and omissions which were considered necessary to complete this work, but could be the pretext for further research.

4.3 The Selected Case-studies

This section lists all the considered case-studies, and provides their geographical and chronological location. This gives the opportunity to sort the case-studies by continent and country, which will be an ongoing distinction throughout the next two chapters.

The application of the survey criteria to the data sources resulted in 197 case-studies throughout eighteen different countries. The case-studies are listed in the first part of this section, and includes data like year of completion, and geographical location (Country, City). This data will be discussed following the list. The findings in the last part of the section reveal that there are differences between the countries in number of built case-studies and when they were built.

4.3.1 The List of the 197 Case-Studies

This part of the study lists all the selected case-studies and divides them into three main groups: Europe, North America, and other countries. The location of the projects is shown in three respective images. In the Table 4.1, 4.2, and 4.3 are included the following data:

- **Name:** every case-study has a name given by one of the stakeholders involved. Some case-studies are known by more of one name, like in the case of *Stadthaus*, which is also known as *Murray Grove*. In the case of double names, only one was chosen. In some cases, a case study is a project composed of a series of buildings. If a case-study was composed of several buildings with similar constructive properties (structural system, EWPs used, appearance), then all the buildings were collected under the same project name (as stakeholders and key players do). If a case-study was composed of several buildings with different constructive properties, then the different buildings were kept divided.
- **Page:** every case-study has a dedicated page in the Appendix where all the main data gathered on the project throughout this dissertation is collected. When available, the one-page description also includes images of the outside, inside and of the construction of the case-study.
- **Storeys:** indicates the number of storeys in the case-study. In Chapter 5, a more specific storeys' analysis is carried out, analysing the actual timber storeys of the case-study. This is important distinction, because there are some case-studies which were constructed with a concrete or steel podium.
- **Year:** indicates the year in which the case-study was completed.
- **Country:** indicates the country in which the case-study was built. The case-studies in Belgium and the Netherlands were collected under the region Benelux, which is usually used to refer to this geographical area. This was done because of the low number of the case-studies in both countries. Chile, New Zealand, and Taiwan were also grouped together in

one section (Other countries), having one case-study each.

- **City:** indicates the city in which the case-study was built. In Figure 4.1, 4.2, and 4.3 the cities are represented where the case-studies were realised, with bigger symbols the more case-studies the city had.

Figure 4.1: Location of European case-studies

Table 4.2: List of European case-studies

	Project *(number, name)*	**Appendix** *(page)*	**Storeys** *(number)*	**Year** *(compl.)*	**Country** *(name)*	**City** *(name)*
1	**Spöttlgasse**	305	5	2004	Austria	Vienna
2	**Mühlweg Bauteil C**	306	5	2006	Austria	Vienna
3	**BMW-Hotel Alpenhof**	307	5	2009	Austria	Reutte
4	**Life Cycle Tower**	308	8	2012	Austria	Dornbirn
5	**Seniorenwohnheim Hallein**	309	5	2013	Austria	Hallein
6	**Wagramerstrasse**	310	7	2013	Austria	Vienna
7	**Illwerke Zentrum Montafon**	311	5	2014	Austria	Vandans
8	**Reininghaus Sud**	312	5	2015	Austria	Graz
9	**Holzwohnbau Rosenstraße**	313	5	2016	Austria	Linz
10	**Hummelkaserne**	314	6	2016	Austria	Graz

11	**Mineroom**	315	5	2016	Austria	Leoben
12	**Holzwohnbauten im Dragoner-Quartier**	316	6	2017	Austria	Wels
13	**HoHo Next**	318	6	2018	Austria	Vienna
14	**Gesundheits.Quartiers**	317	7	2019	Austria	Vienna
15	**Gleis 21**	319	6	2019	Austria	Vienna
16	**HoHo Wien**	320	24	2019	Austria	Vienna
17	**Malmo Hus**	322	5	2008	Benelux	Almere
18	**Les Closières**	323	5	2015	Benelux	Charleroi
19	**Patch 22**	324	7	2016	Benelux	Amsterdam
20	**Kietude**	325	6	2018	Benelux	Namur
21	**Hotel Jakarta**	326	9	2018	Benelux	Amsterdam
22	**Puumera**	328	5	2012	Finland	Heinola
23	**Lintuviita**	329	6	2013	Finland	Seinäjoki
24	**Eskolantie**	330	7	2015	Finland	Helsinki
25	**Puukuokka**	331	8	2015	Finland	Jyväskylä
26	**Mäihä**	332	6	2016	Finland	Seinäjoki
27	**Pihapetäjä**	333	6	2017	Finland	Joensuu
28	**Lighthouse Joensuu**	334	14	2018	Finland	Joensuu
29	**Wood City**	335	8	2018	Finland	Helsinki
30	**DAS Kelo**	336	8	2019	Finland	Rovaniemi
31	**Seinäjoen Tuohi**	337	6	2019	Finland	Seinäjoki
32	**Maison de l'Inde**	339	8	2013	France	Paris
33	**Crous Jean Jouzel**	340	5	2014	France	La Rochelle
34	**Residences J.Ferry**	341	8	2014	France	St.Diè des Vosges
35	**Ywood Les Docks Libres**	342	6	2015	France	Marseilles
36	**Bâtiment Max Weber**	343	5	2016	France	Paris
37	**DDTM**	344	6	2016	France	Vannes
38	**Quai de la Borde**	345	5	2016	France	Ris de Orangis
39	**Rue des Ardennes**	346	5	2016	France	Paris
40	**Lucien Cornil Student Residence**	347	8	2017	France	Marseilles
41	**Opalia**	348	8	2017	France	Paris
42	**Green Office® Enjoy**	349	8	2018	France	Paris
43	**Kibori**	350	7	2018	France	Nantes
44	**Perspective**	351	7	2018	France	Bordeaux
45	**Jo&Joe**	352	8	2019	France	Gentilly
46	**Palazzo Nice Meridia**	353	10	2019	France	Nice
47	**Pont de Flandres B. 007**	354	8	2019	France	Paris
48	**Pop-Up**	355	7	2019	France	Aubervilliers
49	**Pulse**	356	7	2019	France	Saint Denis
50	**Sensations**	357	12	2019	France	Strasbourg
51	**E3**	359	7	2007	Germany	Berlin
52	**Prenzlauer Berg**	360	5	2010	Germany	Berlin
53	**Holz8**	361	8	2011	Germany	Bad Aibling
54	**3XGrün**	362	6	2012	Germany	Berlin
55	**Wälderhaus**	363	5	2012	Germany	Hamburg
56	**WoodCube**	364	5	2013	Germany	Hamburg
57	**C13**	365	7	2014	Germany	Berlin

58	**Kampa K8**	366	7	2015	Germany	Aalen
59	**Nachverdichtung Speyer**	367	5	2015	Germany	Speyer
60	**H7**	368	7	2016	Germany	Münster
61	**Wohnen Offenbach**	369	5	2017	Germany	Offenbach
62	**Woodie**	370	7	2017	Germany	Hamburg
63	**Dantebad**	371	5	2018	Germany	Munich
64	**Lynarstrasse Berlin**	372	7	2018	Germany	Berlin
65	**Famju**	374	5	2019	Germany	Heilbronn
66	**Skaio**	375	10	2019	Germany	Heilbronn
67	**WA14 West**	376	7	2019	Germany	Munich
68	**WA15 West**	373	7	2019	Germany	Munich
69	**Walden 48**	377	7	2019	Germany	Berlin
70	**Residence Alexander**	379	6	2012	Italy	Acquila
71	**Cenni di Cambiamento**	380	9	2013	Italy	Milan
72	**Panorama Giustinelli**	381	7	2013	Italy	Trieste
73	**Marina verde**	382	7	2014	Italy	Caorle
74	**Multipiano Coppito**	383	5	2014	Italy	Coppito
75	**Firenze Ex-Longinotti**	384	6	2015	Italy	Firenze
76	**Palazzina 5 piani**	385	5	2015	Italy	Trento
77	**30 Wood House**	386	6	2017	Italy	Modena
78	**Hotel Nautilus**	387	8	2017	Italy	Pesaro
79	**Residenza Mayer**	388	5	2017	Italy	Trento
80	**5 per 5+1**	389	5	2018	Italy	Trieste
81	**GreenTorino**	390	7	2019	Italy	Torino
82	**Social Housing Vado Ligure**	391	5	2019	Italy	Vado Ligure
83	**Svartlamoen Housing**	394	5	2005	Norway	Trondheim
84	**Egnes Park**	395	5	2010	Norway	Stavanger
85	**Palisaden**	396	8	2013	Norway	Ås
86	**Treet**	397	14	2014	Norway	Bergen
87	**Sørhauggate**	398	5	2015	Norway	Haugesund
88	**Studentboliger Remmen**	399	6	2015	Norway	Halden
89	**Bjølstad Studentboliger**	400	5	2016	Norway	Fredrikstad
90	**Moholt 50/50**	401	9	2016	Norway	Trondheim
91	**Ringerike Campus**	402	5	2016	Norway	Hønefoss
92	**Dramsvegen**	403	8	2017	Norway	Tromsø
93	**Øvre Sund**	404	5	2017	Norway	Drammen
94	**Fagerlund studenthybler**	405	6	2018	Norway	Horten
95	**Kringsjå studentby**	406	10	2018	Norway	Trondheim
96	**Maskinparken TRE**	407	8	2018	Norway	Trondheim
97	**Bjergsted Financial Park**	408	6	2019	Norway	Stavanger
98	**Mjøstårnet**	409	18	2019	Norway	Brumunddal
99	**Valle Wood**	410	7	2019	Norway	Oslo
100	**Contralaminada**	412	5	2014	Spain	Lleida
101	**Hondarribia Visesa VPO**	413	5	2017	Spain	Hondarribia
102	**ARV8**	414	6	2018	Spain	Madrid
103	**La Borda**	415	7	2018	Spain	Barcellona
104	**15 Buenavista**	416	5	2019	Spain	Madrid
105	**Sundsvall I**	419	6	2005	Sweden	Sundsvall
106	**Limnologen**	420	8	2008	Sweden	Växjö

107	**Portvakten**	421	8	2009	Sweden	Växjö
108	**Älvsbacka Strand**	422	7	2010	Sweden	Skellefteå
109	**Strandparken**	423	7	2014	Sweden	Stockholm
110	**Åsbovägen**	424	6	2015	Sweden	Fristad
111	**Vallen**	425	9	2015	Sweden	Växjö
112	**Valla Berså**	426	5	2016	Sweden	Linköping
113	**Docenten**	427	8	2018	Sweden	Växjö
114	**Ekologen**	428	5	2018	Sweden	Växjö
115	**Frostaliden**	429	8	2018	Sweden	Skövde
116	**Botanikern**	430	9	2019	Sweden	Uppsala
117	**Kajstaden**	431	9	2019	Sweden	Västerås
118	**Strandsnäckan**	432	5	2019	Sweden	Växjö
119	**Trummens Strand**	433	8	2019	Sweden	Växjö
120	**Holzhausen**	435	6	2006	Switzerland	Steinhausen
121	**Casa Montarina**	436	6	2007	Switzerland	Lugano
122	**Badenerstrasse**	437	7	2010	Switzerland	Zurich
123	**Wohnhaus Habsburgstrasse**	438	5	2011	Switzerland	Zurich
124	**Residenza Sirio**	439	6	2012	Switzerland	Lugano
125	**Mühlebachstrasse**	440	6	2012	Switzerland	Zurich
126	**Giesserei**	441	6	2013	Switzerland	Winterthur
127	**SZU-Betrisbgebaude**	442	6	2013	Switzerland	Zurich
128	**Tamedia Office**	443	7	2013	Switzerland	Zurich
129	**Hotel Saentispark**	444	5	2014	Switzerland	Abtwil
130	**Mehr als Wohnen Haus J**	445	5	2015	Switzerland	Zurich
131	**Siloah**	446	7	2015	Switzerland	Bern
132	**Zollfreilager Housing**	447	6	2016	Switzerland	Zurich
133	**Hotel Revier**	448	5	2017	Switzerland	Lenzerheide
134	**sue&til**	449	6	2018	Switzerland	Winterthur
135	**Suurstoffi S22**	450	10	2018	Switzerland	Rotkreuz
136	**Arbo**	451	16	2019	Switzerland	Rotkreuz
137	**Asylunterkunft Rigot**	452	5	2019	Switzerland	Geneva
138	**Omega Headquarters**	453	5	2019	Switzerland	Biel
139	**Fairmule House**	456	5	2006	UK	London
140	**Stadthaus**	457	9	2008	UK	London
141	**Birdport House**	458	8	2011	UK	London
142	**Whitmore Road**	459	6	2012	UK	London
143	**Kingsgate House**	460	7	2014	UK	London
144	**UEA Crome Court**	461	7	2014	UK	Norwich
145	**Cobalt Place**	462	6	2015	UK	London
146	**Curtain Place**	463	6	2015	UK	London
147	**Trafalgar Place**	464	5	2015	UK	London
148	**Wenlock Road 17-21**	465	10	2015	UK	London
149	**106 Lewes Road**	466	5	2016	UK	Brighton
150	**Nordic Lofts**	467	5	2016	UK	London
151	**UEA Blackdale**	468	6	2016	UK	Norwich
152	**Woodberry Down**	469	5	2016	UK	London
153	**Bacton Low Rise**	470	5	2017	UK	London
154	**Dalston Lane**	471	11	2017	UK	London
155	**Highpoint Terrace**	472	8	2017	UK	London

156	**Hands Building**	473	5	2017	UK	Oxford
157	**Press House**	474	9	2017	UK	London
158	**Boiler House**	475	7	2018	UK	London
159	**Ellerslie Road**	476	7	2018	UK	Glasgow
160	**Pitfield Street**	477	6	2019	UK	London
161	**Green House**	478	7	2019	UK	London

Figure 4.2: Location of North American case-studies

Table 4.3: List of North American case-studies

	Project *(number, name)*	**Appendix** *(page)*	**Storeys** *(number)*	**Year** *(compl.)*	**Country** *(name)*	**City** *(name)*
162	**CSN-Fondaction**	480	6	2009	Canada	Quebec City
163	**UBC Earth Sciences**	481	5	2012	Canada	Vancouver
164	**District 03**	482	6	2013	Canada	Quebec City
165	**Wood Innovation Centre**	483	8	2014	Canada	Vancouver
166	**Synergia**	484	6	2016	Canada	Saint-Hyacinthe
167	**Arbora**	485	8	2017	Canada	Montréal
168	**Lakeside Resort Expansion**	486	6	2017	Canada	Penticton
169	**Origine Condos**	487	13	2017	Canada	Quebec City
170	**UBC Brock Commons**	488	18	2017	Canada	Vancouver
171	**Wilson School of Design**	489	5	2018	Canada	Richmond
172	**Bullitt Center**	491	6	2013	US	Seattle
173	**Radiator**	492	5	2014	US	Portland
174	**Framework**	493	5	2015	US	Portland
175	**38 Davis**	494	6	2016	US	Portland
176	**Clay Creative**	495	6	2016	US	Portland
177	**T3**	496	7	2016	US	Minneapolis
178	**360 Wythe**	497	5	2018	US	New York

179	**Carbon 12**	498	8	2018	US	Portland
180	**First Tech Federal Credit Union**	499	5	2018	US	Hillsboro
181	**Flatiron PDX**	500	6	2018	US	Portland
182	**Adohi Hall**	501	5	2019	US	Fayetteville
183	**Platte Fifteen**	502	5	2019	US	Denver
184	**Sideyard**	503	5	2019	US	Portland
185	**T3 Atlanta**	504	7	2019	US	Atlanta

Figure 4.3: Location of case-studies in other countries

Table 4.4: List of the other case-studies

	Project *(number, name)*	**Appendix** *(page)*	**Storeys** *(number)*	**Year** *(compl.)*	**Country** *(name)*	**City** *(name)*
186	**Forté**	506	10	2012	Australia	Melbourne
187	**25 King**	507	10	2018	Australia	Brisbane
188	**Aveo Norwest**	508	10	2018	Australia	Sydney
189	**Daramu House**	509	7	2018	Australia	Sydney
190	**The Gardens Macarthur**	510	8	2018	Australia	Campbelltown
191	**55 Southbank Boulevard**	511	17	2019	Australia	Melbourne
192	**Gillies Hall**	512	6	2019	Australia	Frankston
193	**Kambri-Student accomodation**	513	9	2019	Australia	Canberra
194	**Kambri-CLE**	514	7	2019	Australia	Canberra
195	**Te Ara Hihiko**	516	5	2012	New Zealand	Christchurch
196	**WoodTek HQ**	517	5	2014	Taiwan	Taichung City
197	**Los Bronces**	518	6	2019	Chile	Los Andes

4.3.2 Where and When MTBs Were Built

The list of the case-studies provided insights on the building location and their time of completion. Figure 4.4 shows where and when the case-studies were built.

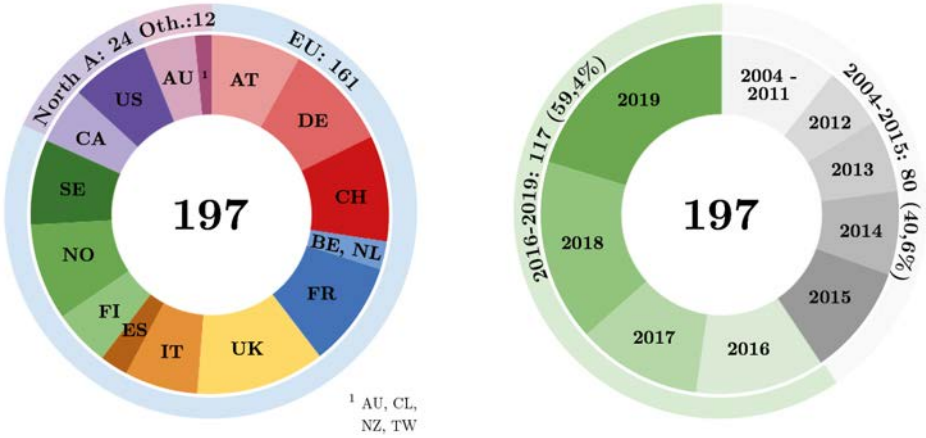

Figure 4.4: Number of case-studies in each country

Europe is the continent with the highest number of case-studies, with 161 built projects. North America has 24 built case-studies, and the other countries have 12 case-studies in total. Through the completion year of the case-study it emerged that, globally, MTBs are a recent phenomenon. In grouping the projects by the year in which they were completed, Figure 4.4 shows that in the last four years (2016-2019) of the survey, 117 case-studies were completed. This composes 59,4% of the total selected case-studies.

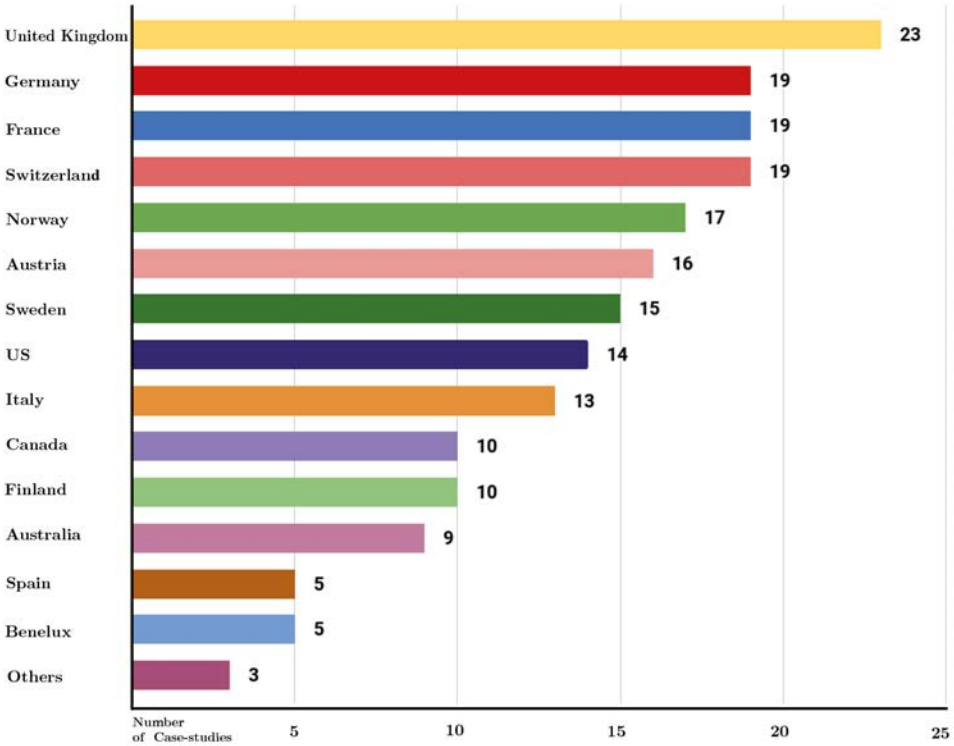

Figure 4.5: Number of case-studies in each country

By performing a simple sum of the case-studies (not buildings or square meters, which will be made in the next chapter), it emerged that the United Kingdom, is the country where the majority of the case-studies are located with a total of 23 projects (see Figure 4.5). The majority of the other countries have more than 8 case-studies each, and half have more than 12.

Figure 4.6 combines geographical location (and world region) with the year of completion, displaying the progressive completion of the selected MTBs over the 15 years surveyed. The chart clearly demonstrates that countries completed MTBs later than others. The first reported case higher than four-storeys was built in Vienna (Austria) in 2004. Sweden and Norway followed shortly thereafter. However, the majority of the other countries built the larger part of their case-studies in the very last years of the survey. The last two years in particular were the years with the highest completed projects, 32 and 40 case-studies respectively.

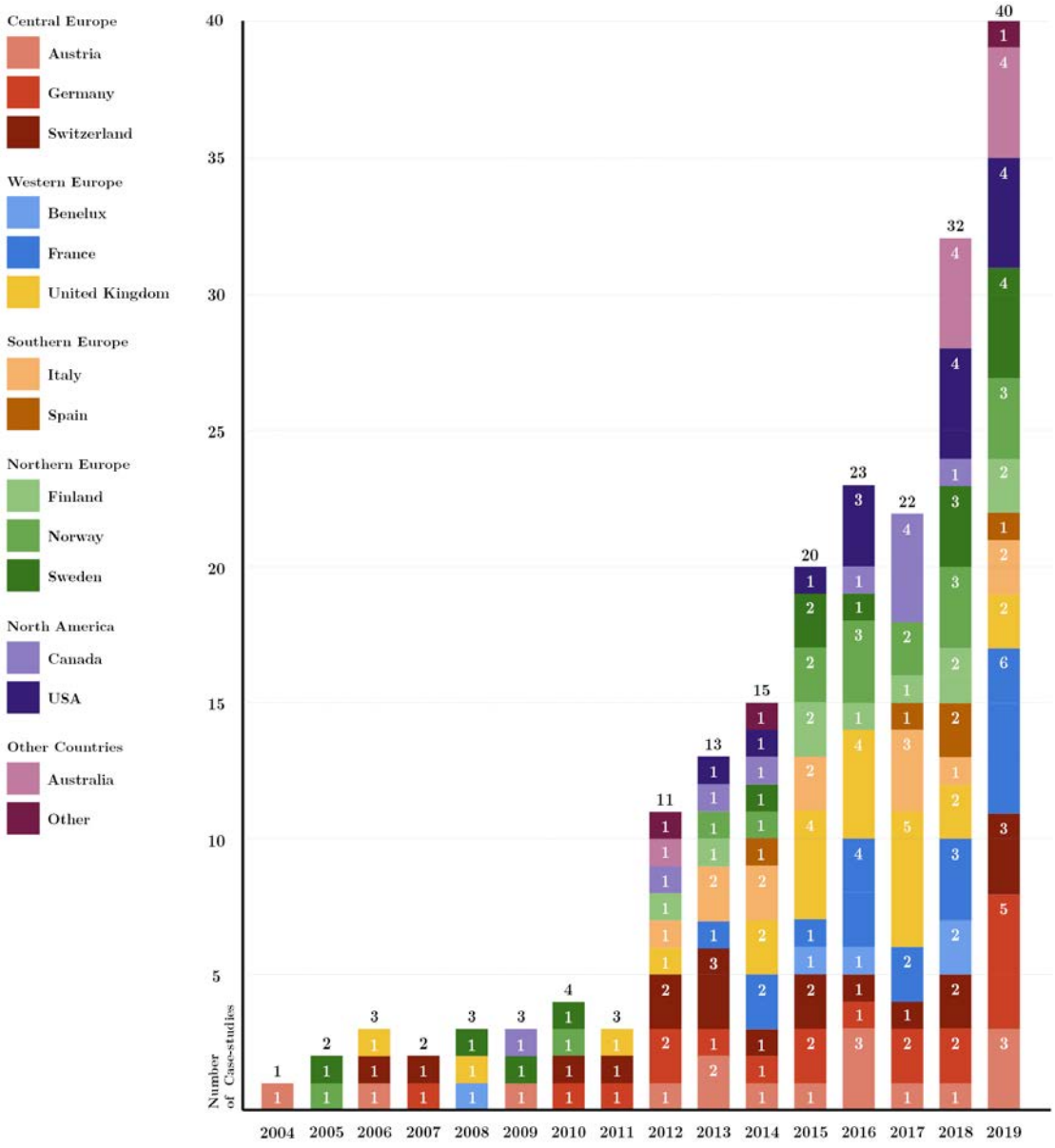

Figure 4.6: Number of case-studies divided per completion years and by country

A positive outcome which can also be observed, is that even though countries like France and the United States started a bit later than others, they still have managed to build a high number of case-studies. This implies that several buildings were realized over a short period of time, which can be encouraging to countries who have fewer cases.

4.4 Conclusions

This chapter analysed and discussed the existing literature on comparative survey on MTBs. What emerged is that there are several open points left by previous studies. The main point is the common height-threshold set by the analysed studies which did not allow their research to include mid-rise buildings. Therefore, a comparative survey which also includes mid-rise MTBs does not yet exist. The inclusion of projects below the previously set height threshold was necessary to both enrich the literature, and give a better overview of the state of the art of MTBs. Furthermore, the literature lacks a proper analysis of the stakeholders involved in the realisation of MTBs throughout the years. It is true that some previous surveys reported the influences and role of the stakeholders, however only one source showed that there are relationships between case-studies and stakeholders, and this was observed in a limited number of case-studies, with all the cases being above seven-storeys.

In light of these observations, the survey methodology section set the criteria for the selection of the case-studies. The case studies included in the survey were built from 2004 (this was the year the world's first five-storey MTB was completed), and included cases from five-storeys and above. Projects under construction were not included. The survey stops at the end of 2019, due to the need for the dissertation to be completed by the end of 2020.

These criteria allowed data to be selected from the 197 case-studies built in 18 countries. The last section of this chapter grouped the projects into three continental groups, and put them in chronological order. This gave the reader an overview of the location and the period in which the selected case studies were built. The case-studies are not evenly distributed between the countries. Some countries have a far higher number of completed case-studies in comparison to others. The analysis of the chronological completion of the case-studies, showed that MTBs are a recent trend in construction, with the majority of the selected case-studies having been built in the last four years of this survey (2016-2019).

All in all, this chapter highlighted the location and the time in which the case-studies were completed. This gives a first glance to national differences. The next chapters will further analyse how these case-studies differ and why these differences exist.

Chapter 5

Design Analysis

As explained in the introduction of this dissertation, MTBs are buildings in which the main structure system is based out of solid wood elements. The previous chapter defined the criteria and listed 197 built case-studies. The list also included their completion date and location. Moving onward, the goal of this chapter is now to understand in what ways these case-studies differ from one another, if there are similarities between countries (this was already suggested by a study in the literature review), and if there are design differences which are worth underlining and investigating further.

In order to answer the research questions, this chapter first defines the existing literature of structural analysis regarding MTBs. The structural analysis represents a central topic in this dissertation. The existing structural categories were combined and enriched by the author, who defined 32 categories. Cores, podium, and floor slabs of the projects were also described and compared. Once the set of structural categories is clarified, the section proceeds with the description of other design characteristics researched in the case-studies. This includes characteristics such as program, external facade cladding material and timber exposure inside the building. Once the framework of the research is defined, the case-studies are analysed following the order of the list in Chapter 4. Every country has its own section in which the data are discussed. Some case-studies are described in greater detail if they were a representative country-example or interesting from a technical solution perspective. Every country analysis is supplemented with a summary table where all the main surveyed data are collected. Therefore, the focus of the next pages is on identifying and describing how MTBs were built, how their structure was designed, what they look like on the outside and inside, and what the similarities or differences are between the cases in each country and between other countries. At the end of this chapter, a final section summarizes and discusses the major design findings. Overall, the pages that follow are not an encompassing descriptive list of all the MTBs in the world. The goal is to highlight and understand the characteristics of the national differences of the case-studies. Some data gathered in this chapter will be further discussed in Chapter 6 and in the Conclusion Chapter of this dissertation, where the overall observations and references to the findings of this chapter will be made.

5.1 Literature Review of the Design Analysis of MTBs

The existing literature on design analysis is mainly focused on the structural categorisation. Seldom have other design aspects been widely compared. A large part of the literature on MTBs has been dedicated to technical issues such as structural or fire behaviour analysis, however some publications have attempted to structurally analyse MTBs according to different categorisations. The literature in this context presents some differences in the systematisation and in the last part of this section the open points are discussed and evidenced by the author. There were only a few sources interested in comparing other design characteristics such as envelope systems or architectural mass of the selected case-studies. These existing attempts found in the literature are briefly described and discussed.

5.1.1 Literature on Structural Categorisation

MTBs' structure is not poured like concrete structures, which form a single compact base, it is actually more similar to steel structures, which are made up of several different elements (Kaufmann et al., 2018). One noticeable difference is that steel buildings are composed of one-dimensional elements (columns or beams) which is not the case for timber structures. MTBs can in fact be formed by one-dimensional or two-dimensional (vertical and horizontal) structural elements, or by 3D modules, which are composed of walls and floors that have been pre-assembled.

Because these elements can be combined in several ways, some authors observed a series of repetitions and were then able to further advance some of the structural categorisations (Hurmekoski et al., 2015) (Brege et al., 2015) (Green and Taggart, 2017) (Zumbrunnen, 2017) (Foster et al., 2017). However, it is worth mentioning that the idea of dividing the structures in general methods is not always agreed upon in literature (Kaufmann et al., 2018). There are different ways academic researches or authors dealt with the structural categorisation of MTBs. Considering that ten years ago there were not very many built and completed examples, the real task of categorizing these structures emerged only once there was a higher number of cases, making the literature on structural categorisation a recent topic. Through studying the existing literature, there are three majors schools of thought:

1. **Platform (pole frame and massive wood), Post-and-Beam and Modular Element** (Erikshammar, 2014) (Brege et al., 2015) (Hurmekoski et al., 2015)

   This categorisation highlights the three different structural systems which differentiate the case-studies. The authors differentiate the platform technique in both pole frame and panel elements, depending on the EWPs used. The difference between platform and post-and-beam lies in the constructive process and on the load-bearing structural elements (walls or columns), whereas the modular element is based on ready-made rooms with several technical installations already assembled.

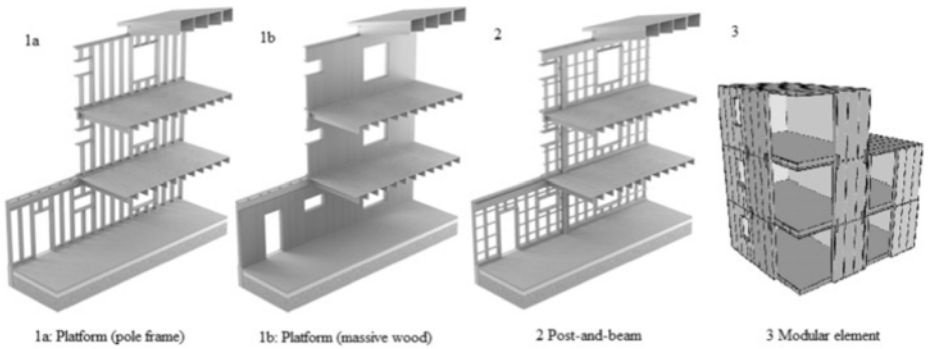

Figure 5.1: The three structural systems considered in Hurmekoski et al. (2015)

Source: woodproducts.fi, puuinfo.fi, and Erikshammar (2014)

2. **Panel Systems, Frame Systems and Hybrid Systems**

   (Green and Taggart, 2017) (Salvadori, 2017) (Kuzmanovska et al., 2018)

   According to this system, MTBs can be categorized into three structures. The first, called the "Panel system", indicates structures formed by solid wall and ceiling panels of mass timber. "Frame systems" (or post-and-beam) are defined as buildings which have their structure supported by an interconnected system of beams and columns. "Hybrid systems" are systems which combine a panel or frame system with other construction materials like concrete or steel, resulting in different technical solutions.

3. **Single material, Composite (timber-steel or timber-concrete), Mixed (timber-steel or timber-concrete)**

   (Foster et al., 2017) (CTBUH Journal, 2017) (Wiegand, 2019).

   This classification addresses the existence of hybrid combinations and structurally categorizes them. In the case of a "Single material building", the authors would define this as a building with a unique material (concrete, steel or timber) which supports both the LLRS and GLRS. A "Composite building" is considered a building in which two or more materials are combined in the structural system. This would be the case for a structure with a concrete core and a timber frame. Lastly, a "mixed building" is a building in which two or more systems with different materials overlap.

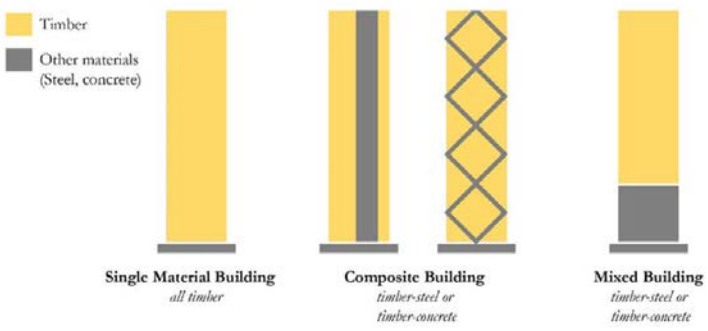

Figure 5.2: The three structural systems in Wiegand (2019)

Source: Wiegand (2019), based on examples and figures in Foster et al. (2017)

All these categorisations have commonalities with each other, each emphasising a different aspect involved in the construction of these buildings. While the first system is the only one which dedicates a category for modular element, the second emphasises the presence of hybrid combinations besides all-timber panel and frame systems. The last system considers the possibility of both overlaps in construction materials and hybrid combinations.

5.1.2 Literature on Other Design Aspects

Besides the structural categorisation, the literature on the comparative analysis of other design aspects regarding MTBs is very scarce. The program (also called "building type") is mentioned in the description of the buildings, but very few studies compare it together with other similar design aspects. Below three different attempts which were carried out in previous researches have been summarised.

1. **Cost, Schedule, and Safety Data** (Smith et al., 2015)

   One of the first comparative reports on solid timber projects is divided in three parts. The first deals with the comparison of general information such as year completed, building type or site context of the case-study. A second part is focused on cost. The report provides a series of cost-related information such as design or solid timber cost. However, many case-studies are not described due to lack of information. Another section to be compared is dedicated to the scheduling data, like project duration and design duration. Also in this case, several data points were missing. Finally, a qualitative section refers to quality and safety issues.

2. **Structural Materials, Facade, Comment on Sustainability** (Salvadori, 2017)

   This master thesis was mainly focused on structural analysis (system, materiality of beams, columns, ceiling and core). Additionally, the fire strategies were described, as the indoor timber exposure. In a facade analysis section, the material used for the external cladding was indicated and other characteristics were mentioned such as the presence of balconies and loggias. Finally, the sustainability section addressed the energy related information, the tons of CO_2 sequestered by the structure and the energy certifications obtained by the buildings (such as LEED or BREAM). However, the last level of analysis was rarely described due to the lack of information.

3. **Envelope System and Architectural Massing** (Kuzmanovska et al., 2018)

   This study applies three survey lenses to the list of case-studies involved. Under the "Structural" lens, the authors analysed the material and location of the core along with the podium and other articulations of the structural system such as fire strategy implications (columns/beams visible or timber on ceiling). The "Envelope system" analysis deals with the description of the structural strategy, transparency, the level of prefabrication, and architectural expression. Finally, the last lens "architectural massing" describes the case-studies according to their building volume, the balcony strategy, and circulation.

These different design categorisations are focused on heterogeneous data. The last two attempted to described other design aspects such as envelope and architectural massing. Lack of data was often a problem for the researchers and often some descriptions were not possible.

5.1.3 Lessons Learned from the Literature Review

As previously mentioned, the descriptions of the existing structural categorisation are similar but emphasises different elements. From the previous literature analysis, it's possible to collect some general comments which are reported below:

1. **Hybrid systems/combinations:** two categorisations acknowledged the role of hybrid timber-based systems, with the one following the guidelines of Foster et al. (2017) more focused on the relationship between timber and other materials. As it will be later shown, hybrid combinations are frequent in the construction of MTBs and the number of hybrid buildings is high. Therefore, the presence of hybrid combinations needs to be included and properly described.

2. **Platform, Panel systems, and Panelised:** the first two categorisations acknowledge the existence of a structural system based on solid timber walls and ceiling elements. Thus, no agreement has been reached regarding the name of the system in the existing literature. Both the terms refer more to the technique of building, not strictly the structural system. In other publications they have been called different names, including "Panelised", which in author's opinion, is more appropriate, because it identifies the elements of the structure (panel elements) formed by load bearing walls.

3. **Post-and-beam or Frame systems:** as for the previous point, both the first two categorisations highlight the existence of structural systems in which columns and beams play a main role in the LLRS and GLRS. The spatial and structural differences between panelised and post-and-beam have been evidenced in previous studies.

4. **Modular element:** the structural implications of a modular element are different when compared to a traditional panelised structure. Logistic and assembly of the elements also differs. In light of these considerations, it is also important to include 3D modular element in the structural classification of MTBs.

5. **Feasibility of data analysis:** the existing literature on survey on MTBs showed some limitations regarding the design analysis. Some data analysed by previous authors did not provide a complete overview of the projects due to lack of data. This is the case for the analysis of the cost or schedule (Smith et al., 2015) or sustainability data (Salvadori, 2017). This research showed that there are data points which can be feasibly gathered, and some which cannot, especially for a sample of 197 case-studies. At the same time, envelope analysis and architectural mass are available as data points, and they could be enlarged to include similar topics such as indoor timber exposure.

Based on these comments, the next section will describe the survey methodologies adopted, with the selected combination of structural categorisation, and the design considerations. The variety and complexity of the 197 selected projects was considered too wide to be analysed by the categories previously defined in existing literature. By observing the structural systems used in the analysed projects, it was considered necessary to enlarge the spectrum of categories, considering not only the general concept (panelised, post-and-beam or modular) and materials (timber, concrete, steel) but also more specific lateral load strategies applied on the structure.

5.2 Survey Methodology of the Design Analysis

The question that this chapter wants to answer is: how were MTBs designed? In order to do so, this part of the design analysis is done through a comparative survey. The literature revealed several structural and design analyses of the case-studies. In light of the lessons learned from the literature, along with the observations of the selected case-studies, this dissertation introduces 32 structural categories. An additional and separate analysis is carried out on the core, podium and floor slabs of the selected projects. Having clarified the main structural categories, this analysis will proceed with the description of other design aspects surveyed. These include program, external cladding, indoor timber exposure, and building volume.

The case-studies are divided by country (or group of countries) as already shown in Chapter 4. Each country has a dedicated section where the analysed data are discussed and presented. Some case-studies were described in more detail if they were determined to be particularly relevant. Data were gathered from the data sources described in Section 1.3.2. This analysis of the case-studies describes the practice of MTBs in each country and highlights their main characteristics. A final section compares all these separate findings in order to show the most common practices and properties of the global MTBs. By doing so, trends and differences will be laid out and discussed.

5.2.1 Structural Categorisation

The structural categorisation of this dissertation is based on a combination of the three systems observed in the literature and discussed in Section 5.1.3. The division *Panelised, Post-and-beam and 3D Modular element* is combined with material combinations (all-timber, timber-concrete, timber-steel, and timber-concrete-steel) which created an initial ten categories. Timber-steel and timber-concrete-steel combinations with 3D modular element were not found. The categorisation made by Foster et al. (2017) emphasises the way the materials are combined. In light of this, within the ten categories, other sub-categories were identified according to the way the different materials were juxtaposed or combined. Podium, core, and podium-core were the main type of subgroups identified. The result derived from this process was the identification of 32 structural categories (see Figure 5.3).

An MTB is a complex building combined with many structural and design elements. Categorising all MTBs into 32 structural categorisations can often be considered imprecise and not completely correct by other experts. It is worth mentioning that the categorisation here is purely indicative of the main structural system of the building. Some projects which were categorised as panelised for example, can still have columns or beams in parts of the plan when, for architectural design and choice, openings or bigger spans were necessary. Buildings categorised as all-timber, may have some steel beams or columns. Buildings which are considered timber-concrete, can also have secondary steel elements. MTBs also include a wide range of materials, such as connections (these are not discussed in this dissertation), which most of the time are made of steel. A better description of specific categorical properties is shown below. This clarifies what the main aspects were, when creating a specific classification.

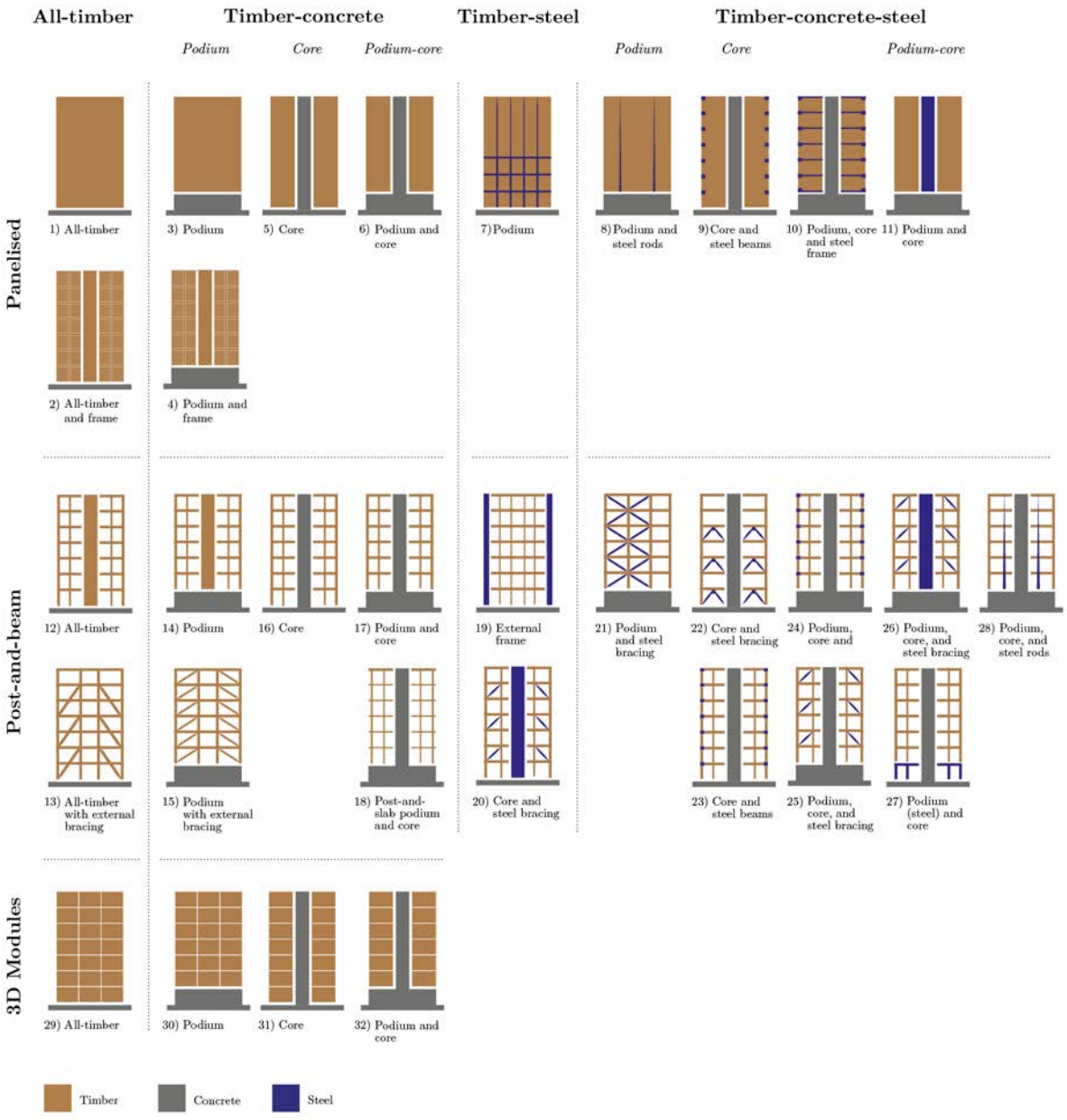

Figure 5.3: The matrix of the structural categorisation used in this study

Panelised

Panelised systems, are based on load bearing plate elements, which can be further divided into floor and wall elements, according to their orientation (Falk, 2005). The majority of the walls are load-bearing and this reduces the thickness of the panels to a minimum. Sometimes a panelised building can also have load-bearing external walls which are often assembled on the tops of floors, storey by storey (Hurmekoski et al., 2015). They usually form honeycomb or party wall structures (Zumbrunnen, 2017). Stiffness is therefore achieved via the walls which carry both the lateral loads (wind and seismic) and gravity loads together with the floor slabs. This limits the flexibility of the plan of the building, because this structure means that many walls cannot be removed. Some case-studies were instead formed by a central core and external load bearing walls which are connected with the floor slabs. In hybrid timber-concrete or timber-steel buildings, the LLRS is either a concrete core or a steel-based system (Karacabeyli and Gagnon, 2019).

- **Panelised all-timber:** solid timber elements form the main structural system in this category. Two sub-categories were identified. The first category can be identified as "solid walls" in which CLT walls form the core which resists the lateral loads, together with shear walls made of other EWPs, but mainly CLT (1). In another sub-category, the prevalent panelised system is combined with internal columns and beams (2). Buildings with this system, have therefore mainly load-bearing walls in the facade and inside the plan, but a supplementary role is played by the glulam frame. Sometimes some steel beams or steel columns are also used, but they have a secondary role. Floor slabs can be made of CLT or by box-floor elements composed of different EWPs. The timber structure is directly anchored to the concrete foundations, requiring special detailing for possible water leaks at the ground level.

- **Panelised timber-concrete:** the buildings included in this category can have three different concrete combinations. A first group (3), has simply a concrete podium on which an all-timber structure is anchored. The core of the case-studies of this category are made of CLT, or in some rare cases, of LVL. In some case-studies, on the top of a concrete podium, a panelised-based all-timber structure included many columns and beams, resulting in a combined panelised-post-and-beam system (4). Depending on the presence of a concrete podium, or lack thereof, the other two combinations resulted in situations where a timber panelised structure is anchored to a concrete core (5) (6). The connection to the concrete core is one of the main details in these structures which involves a set of different technical solutions. Floors can be made of EWPs or hybrid timber-concrete floor slabs.

- **Panelised timber-steel:** this category includes buildings in which some structural role is played by a steel frame at the lower level of the building (7). The frame, which forms the podium of the building, is connected to CLT load-bearing walls which helps stiffen the structure. Additionally, other steel columns run up to the top of the building. CLT floor slabs constitute the GLRS of the building together with the other load-bearing structural elements.

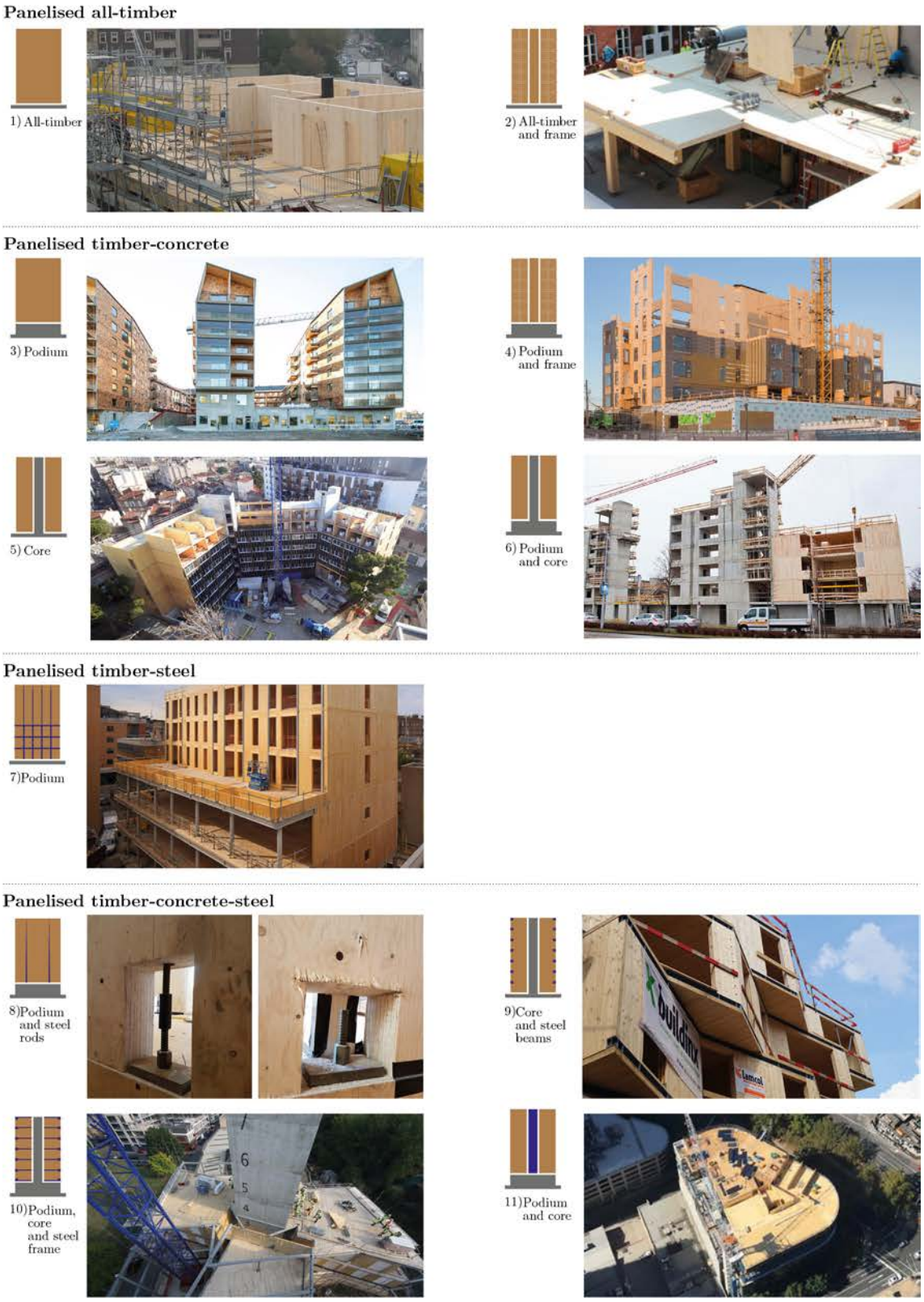

Figure 5.4: Panelised structural categories

Source: Service Legno, CecoBois, Fojab, Nordic Structures, Benoit Wehrle, Bruno Klomfar/pro Holz, Waugh Thistleton Architects, Keskisalo (2018), Ney&Partners, Tim Crocker, Hawkins Brown Architects

- **Panelised timber-concrete-steel:** the combination between timber, concrete, and steel created three different sub-categories. The first type of combination has a concrete podium on which steel rods anchor the timber structure. They run from the podium up to the roof of the building, located inside the walls. Thanks to this system, the core can be made of EWPs (8). In two similar categories, a concrete core forms the main LLRS, whereas steel beams (9) or a steel frame (10) are connected to CLT walls and floor slabs. The latter sub-category has a concrete podium on which the rest of the structure is built. The additional shear walls and floor slabs are made of EWPs. Another category includes buildings like *55 Southbank Boulevard* which were built above an existing concrete building. The LLRS of the structure is composed of two steel-frame cores and the rest of the building has a panelised system made of CLT (11).

Post-and-Beam

Post-and-beam systems consist of columns and beams interconnected to form a stiff frame which can withstand the lateral loads (Green and Taggart, 2017). The frame is usually anchored to a core and can have additional stiffening elements made of diagonal EWPs beams or steel. There are several combinations of elements and materials. Sometimes the structure can consist simply of a timber frame. In this case, in order to achieve lateral stability, additional bracing systems like shear walls, diagonal EWPs or steel beams, and steel cross bracing have been designed. Sometimes these structures can be on top of a concrete or steel podium. Other times, the system can adopt a strategy similar to traditional concrete buildings where a central core provides the stiffness to the structure. In this case the columns are located around the core and are connected with beams (Zumbrunnen, 2017). Floor slabs are usually supported by the main frame, or they can be made of different EWPs combinations, like hybrid glulam-concrete floors which consist of pre-assembled glulam beams connected to a concrete topping layer. Another less frequent system is called post-and-slab. This was considered separately.

- **Post-and-beam all-timber:** there are two observed configurations in the design of post-and-beam structures with all-timber, depending on the presence, or lack of an additional timber bracing system. One system (12) relies on the stiffening made by both a frame (usually glulam) and a core (usually CLT). These elements are connected and anchored to the foundation of the building. Floors are made of EWPs-based products. In the other system (13), columns and beams carry the main loads, with continuous bracing diagonal beams which stiffen the structure. The core is also made of EWPs, but it does not have a relevant structural function. As with the case of panelised systems, buildings which have some steel elements integrated in the structure but with a secondary structural role, were still included in these categories. Case studies with a few floor slabs made of concrete like *Treet* and *Mjøstårnet*, were considered simply post-and-beam structures, also following the CTBUH certification (CTBUH, 2019).

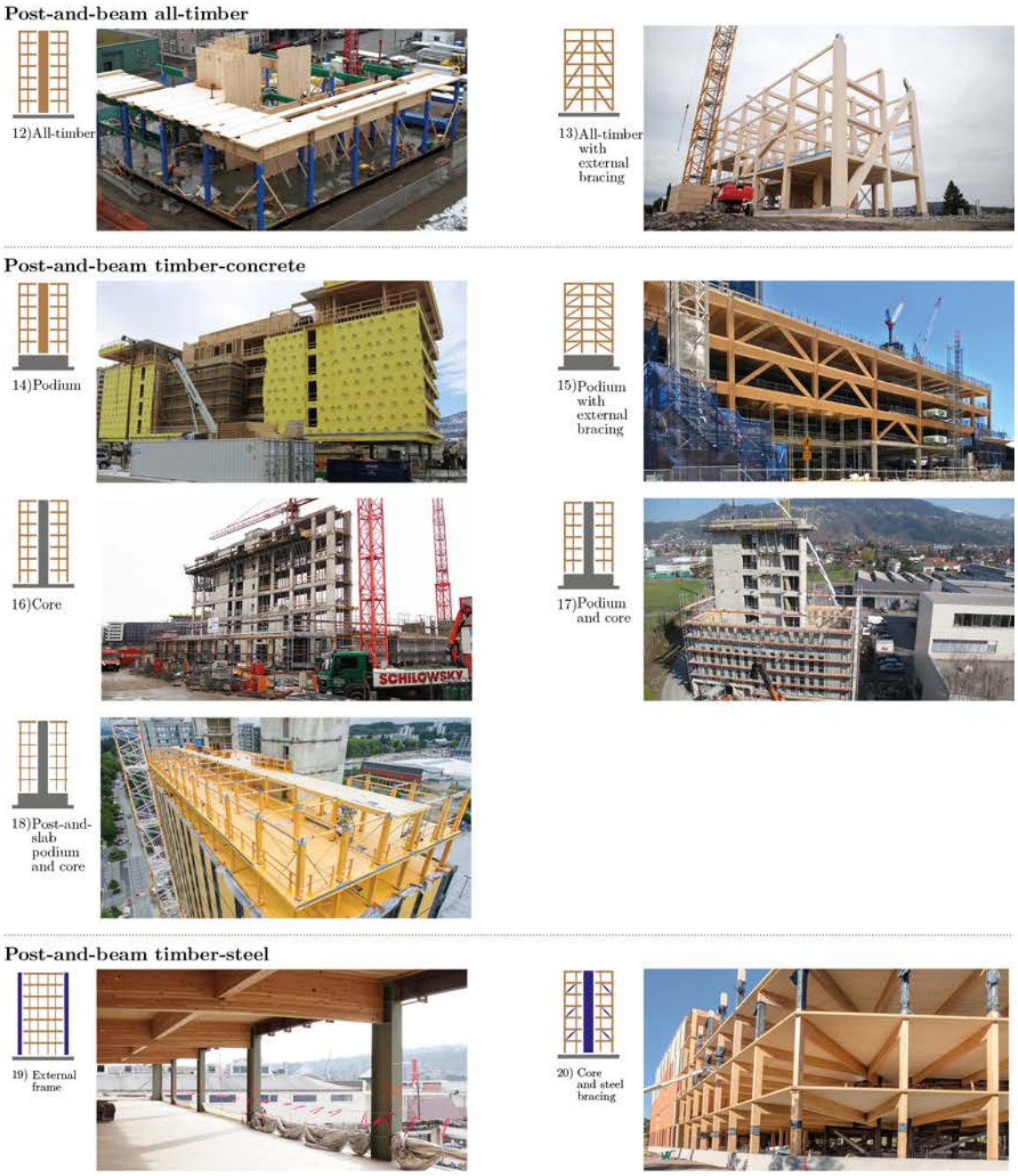

Figure 5.5: Post-and-beam structural categories

Source: Micheal Green Architecture, Moelven, PLR-Construction, Lendlease, Handler, CREE, KK Law, Justin Sherrill, Structurlam

- **Post-and-beam timber-concrete:** the hybrid combination of timber and concrete in post-and-beam structures resulted in four different categories. The first category (14) is composed of buildings with a timber frame structure on top of a concrete podium. Concrete is only located at the bottom, whereas the rest of the structure (core included) is made of EWP-based columns and panels. In a similar category, diagonal beams can be included in the LLRS in order to stiffen the structure (15). In the other three categories the timber frames of the projects are connected to a concrete core (or cores). In two-subcategories the core of the buildings takes the main lateral loads, meanwhile the GLRS is formed by columns and beams which support EWPs or EWPs-based floor slabs. The difference can be found according to the presence, or lack of, a concrete podium (16)(17). Another category includes buildings whose structures are formed by a concrete core (or cores), columns and floor slabs (18). Based on the post-and-beam principle, in this system the traditional role made by the beams is made by the floor slabs. This is possible thanks to special connections which transfer the loads between the elements. The project *UBC Brock Commons* was categorised under this system, and is the only case-study in the survey which was built in this manner.

- **Post-and-beam timber-steel:** two categories resulted from the combination between timber and steel, both including relatively few case-studies. In the first group, a EWPs frame is connected and stiffened by an external steel frame (19). Floors can be made of EWP-based products and some steel internal bracing can be designed inside the structure as well. In a second category buildings which have a timber frame connected to a steel frame core are included (20). Additional (external or internal) steel bracing systems have also been designed to provide additional stiffening to the structure. Floor slabs are made of EWPs, and they are supported by the EWPs frame of the building.

- **Post-and-beam timber-concrete-steel:** the combinations between timber, concrete, and steel are numerous and eight different structural solutions were found. In a first category, an external steel frame stiffens the entire timber frame structure (21). The other six categories have a concrete (or steel) core which is the main LLRS, together with different steel structural solutions. In one category, a steel bracing system stiffens the entire timber frame structure which can have both frame and floor slabs made of EWP-based products (22). Two categories have steel beams which are located on the edge of the facade. Steel beams can also be used inside the building. The difference between them is the presence of a concrete podium (23)(24). Two categories have both a concrete podium and steel bracing, but differ in the material of the core. In one case the core is made of concrete (25), in another case the core is made of a steel frame (26). Another category has a steel podium and a concrete core takes the main lateral loads in combination with a timber frame (27). In the last category, pre-stressed steel rods inside the timber frame were designed to withstand earthquakes (28). The timber frame sits atop a concrete podium and is connected to the concrete cores.

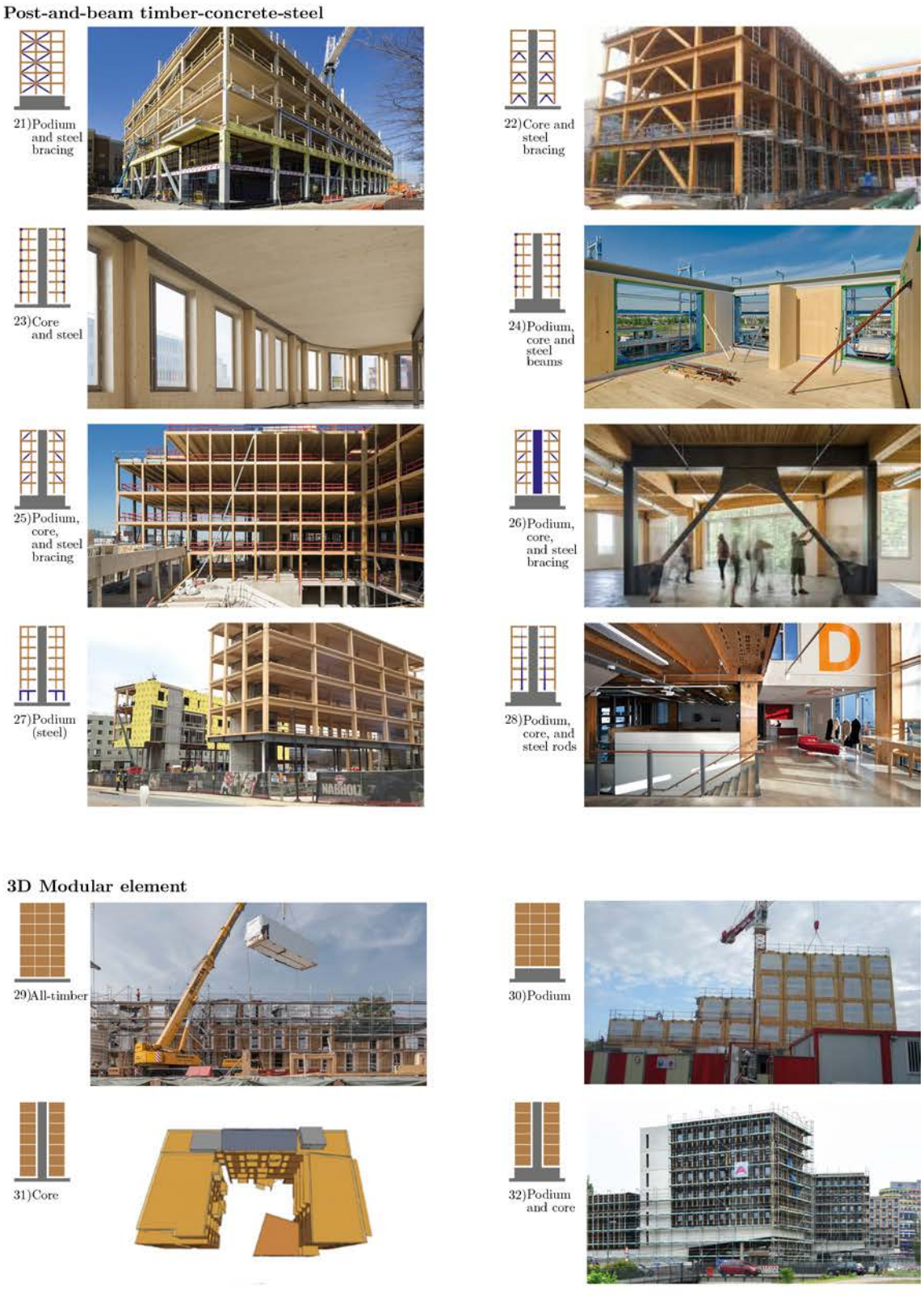

Figure 5.6: Post-and-beam and 3D Modular structural categories

Source: Hines, Structurlam, X, Züblin Timber, Baumschlager Eberle Architekten, Nic Lehoux, modusstudio, Matt Paterson, Enric Rovira and Marcel Kultscher, KLH UK, arketipomagazine, Quandt

3D Modular Element

In this category are included the structures which are made of many similar 3D modules. The specification of the term "3D" is necessary. There are many case-studies which have some of their parts pre-assembled and in this category only buildings formed by 3D pre-assembled volumes are considered. This system is based on ready-made rooms with the doors and windows, electricity appliances, heating, plumbing and ventilation installations already installed. These modules are manufactured off-site and transported afterwards onto the building site with trucks. As for the two previous systems, there are several combinations, but only with concrete (podium, core, or both).

- **3D Modular element all-timber:** in this system, solid or timber frame walls and floors elements are prefabricated and assembled together in order to form a 3D module (29). The core of the building could be erected separately (made of EWPs) or could also be modularly like the rest of the buildings.
- **3D Modular element timber-concrete:** hybrid variations exist within concrete. 3D modular element can be stacked on the top of a concrete podium (30) or directly at the ground floor level, but having a concrete core which stiffens the entire structure (31). Alternatively, the same structure can have both a concrete podium and core (32). In this category, some buildings have hybrid timber-concrete floor slabs.

5.2.2 Other Structural Design Aspects

The previous description of the different structural categories showed the heterogeneous spectrum of solutions which exists in the selected case-studies. In order to properly display the differences in LLRS, and better describe the floor slabs, this section is dedicated to the analysis of other structural design aspects, which can be seen as an addendum to the structural categorisation. The analysis of the generic structural shape of the buildings, the material of the core, the level of the podium, and the materials used for the floor slabs concludes the structural analysis carried out for this dissertation. This analysis follows the existing literature approach and enriches it with a higher spectrum of materials and combinations.

Core

The core of a building is often the main LLRS of the building. It hosts the security escape routes, elevators, and shafts. Sometimes it also hosts main circulation stairs. The shape, number, and length of the core varies across the different case-studies. Often the core is a compact element in the middle or on the periphery of the plan. Other times it stretches along the entire plan. It can also be that the building can have a series of compact or long combined cores. The case-studies of the different cores were analysed and categorised according to their main structural materials. No

specific analysis of the location or the shape of the cores was performed, being that some plans of the case-studies were not available or poorly described.

- **CLT:** cores can be formed by CLT panels of varying thickness, usually characterized by the maximum panel dimensions. These panels are assembled on-site or pre-assembled and then positioned in the correct location.
- **LVL:** an alternative material for CLT is LVL. The LVL panels have varying thicknesses and sizes and are connected together. They can also be pre-assembled or assembled directly on-site.
- **Concrete:** reinforced concrete cores can be poured before or during the erection of the timber structure. They can also be formed by prefabricated parts later assembled on the building site. In these cases, special connections to the timber structures require special consideration.
- **Framed Steel:** in this type of core, steel elements are connected together to form a stiff frame. Beams or walls of the timber structure are directly connected to it with different types of connections.
- **None:** in some case-studies no structural core was identified because the structure relied on other LLRS, mostly external bracing systems. This was the case for a few projects which were all post-and-beam systems. However, in some case-studies the core had no main structural role, but was made of timber, concrete or steel. In this case it was defined by one of the previous categories.

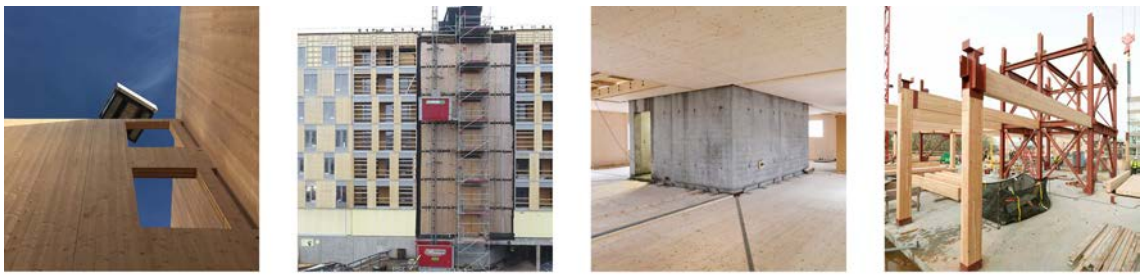

Figure 5.7: Core examples
(a) CLT, (b) LVL, (c) Concrete, (d) Framed steel
Source: Waugh Thistleton Architects, Stora Enso, Martin Kunze, John Stamets

Podium

All the MTBs except one case-study (*Asylunterkunft Rigot*) have a reinforced concrete foundation. In some cases, the mass timber structure can start immediately at the ground floor level, or it can have a podium. In this study, a "podium" is intended to be *"the lower portion of a building which is distinct from the building mass of the tower above"* (Kuzmanovska et al., 2018). The

analysis of the podium highlights the varying podium heights of the selected MTBs. A common practice is to have a concrete (or less frequently, steel) podium. There are several reasons why designers plan a building with it. One reason is durability. By lifting the timber storeys to the first floor, water infiltration at the street level can be avoided. Other possible reasons can be the need to have a more flexible ground floor (due to different programs at the bottom floors), or due to structural or building regulation reasons. In some countries, a concrete ground floor was required by the regulatory framework. The height of the podium is directly connected to the number of mass timber storeys of a building. In many cases, a building which is believed to be a five- (or more) storeys, in actuality has different timber storeys. In this context, buildings were categorised according to these following categories:

- **Ground Floor:** if the podium consisted of only the ground floor of the building.
- **Up to first floor:** if the podium reached the first floor.
- **Up to second floor:** when the building's ground floor, first floor, and the second floor are made of concrete
- **Above existing building:** some case-studies are, in actuality, an addition to an existing building. In this case they were identified separately in another category. Both the projects which are considered additions in this survey are on the top of an existing concrete building.
- **None:** in some cases, the mass timber structure was designed starting directly at ground floor level. In this case, no real podium can be identified. Often the panels are not directly connected at the lowest level of the ground floor, but usually concrete protrusions of 10-15 cm are designed. On the top of these protrusions, are the panels. The same could be done for the columns. Concrete or steel connections are designed to avoid the bottom of the column being elevated from the lowest ground floor level.

Floor Slabs

The floor slabs are part of the GLRS of a building and constitute a high percentage of the material used in the structure. As other publications, books, and researches explained, there is a wide range of EWPs which can also have many combinations. These can be combinations which include other EWPs or concrete. Below the main floor slabs categories are listed:

- **CLT:** is widely used for the floor slabs. Depending on the span of the floor, the panels can have different thicknesses.
- **CLT-concrete:** an alternative combination is represented through hybrid CLT-concrete floors. These hybrid combinations can be pre-assembled before arriving in the building site, or the CLT slabs can be prepared already in place to the final layer of concrete, which is poured directly on-site. For this kind of combination, special attention is dedicated to the method in which the two materials are connected.

- **CLT-glulam:** in some cases, CLT floors can be supported by glulam beams. This combination allows the CLT thickness to be reduced thanks to the presence of the beams. Glulam beams can be pre-assembled together with the CLT panels and transported to the building site, or be assembled in-place.
- **DLT:** these type of floors are screw-free panels which can be used in MTBs. They are formed by stacked boards which together form a panel.
- **DLT-concrete:** in some cases, DLT floors can be combined with a concrete layer on the top.
- **Glulam:** beams made of glulam can form the slabs of MTBs. The floors can be composed of pre-assembled box elements or a series of glulam beams which take on the main loads. In this last case there are usually two rows of them.
- **Glulam-concrete:** a hybrid combination is possible with glulam beams and concrete. As for the CLT-concrete floors, the elements can be pre-assembled off-site and then brought in the building site. Also in this case, special attention to the connection between the two materials has to be given.
- **LVL:** floor slabs made of LVL in MTBs are usually formed by box-elements with insulation in-between the thin LVL beams.
- **LVL-concrete:** a possible combination is combining an LVL-box with a top layer made of concrete.

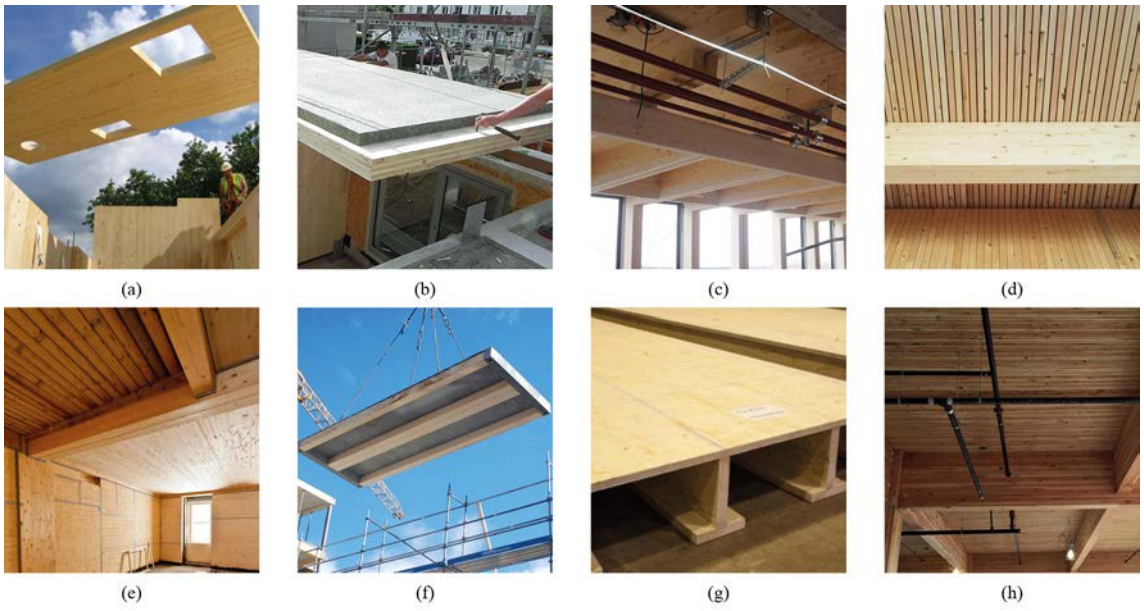

Figure 5.8: Floor slabs examples

(a) CLT, (b) CLT-concrete, (c) CLT-glulam, (d) DLT, (e) Glulam, (f) Glulam-concrete, (g) LVL, (h) NLT

Source: Quay 2c, Kirchdorfer Gruppe, BFV, Structurecraft, arketipo, Stora Enso and Timberpoint Oy, Turnerconstruction

- **NLT:** floors composed of NLT are formed by boards nailed together. Together, these boards form panels which are used in several MTBs.
- **NLT-concrete:** as in other cases, NLT floors can have a layer of concrete.
- **Others:** besides these frequent combinations, other EWPs or EWP-based products were used in the selected case-studies. This category collects all the combinations which involve different EWPs, one-case materials or timber floors which are unspecified.

5.2.3 Other Design Aspects

In this section the other design aspects which were used to analyse the selected case-studies are collected. Many of these aspects are typical of other previous studies such as program or total square meters. The categorisation which follows here is therefore based on the set of the existing literature.

Number of Buildings

In Section 4.3.2, Figure 4.5 displays the number of case-studies related to the country in which they were completed. In reality, these projects are occasionally composed of several buildings which share similar or identical shapes, structural systems, facade cladding, etc. In this category of analysis, the actual number of buildings is identified. No detailed list of the different possibilities is made here, due to the fact that the projects range from 1 to 8 buildings. Not all the buildings which were part of the same building development were counted. *Reininghaus Sud* for example is composed of fourteen different buildings, but only two of them met the height criteria of the survey (taller than four storeys).

Total Built Square Meters

As also reported in previous publications and books, the total square meters of every project were identified and reported. The data found in this category often differed depending on the source. In some cases, it was not clear if the amount reported indicated the net or the overall square meters. Therefore, the numbers presented can only be indicative and should not be considered completely accurate. An MTB can range from slightly more than 400 m^2 of *15 Buenavista*, to the around 55,000 m^2 of *Arbora*.

Program

The programs (also called building type) of the selected projects were analysed following the categories below. These categorise derived from the existing categorisations present in the existing literature on MTBs' surveys. The literature is in generally homogeneous in the differentiation,

but often uses differing terms for the same function. Some projects analysed are large building developments which can cover several functions inside the same building, especially at the ground floor. The categorisations made usually covers the main function present in the building, rather than including all possible functions. Many student housing or residential projects have, at their ground floor level, different functions like stores or cafes. Mixed use programs were considered only in cases where the functions were present at the ground floor only.

- **Residential:** residential buildings are considered all the buildings in which their major function is to provide housing.
- **Social Housing:** a special differentiation is made in the case of projects which are the result of a social housing development.
- **Co-Housing:** are the residential projects which consist of private flats but have shared spaces like libraries, party rooms, etc. These buildings are financed and designed with the direct involvement of the owners, which formed a co-housing group of investors.
- **Mixed Use - Residential and other:** in some cases, the main residential program of a building had additional functions such as a hotel or a restaurant on more than one floor. In these cases, a specific category was introduced.
- **Mixed Use - Residential and office:** some projects share an equal or similar ratio of residential and office spaces.
- **Office:** an office building was considered a building which has the main program as office even if in some cases, other minor functions were present.
- **Student Housing:** a building whose major function is to house the students with individual and group rooms. This typology also includes projects with other educational purposes like seminar rooms or a Mensa.
- **Hospital:** a hospital program was considered when the major functions were medical facilities. These include medical operations rooms and accommodations for patients.
- **Senior living:** a more specific category was considered regarding the housing of elderly people in a specific housing building. Often these buildings have health facilities included in them.
- **Education:** the education program includes projects whose main function is as an educational building. University rooms and functions related to education are all included in this typology.

Exterior Cladding

What do these buildings look like? The visual appearance of these buildings is relevant to understand design differences. Building regulations might limit the exterior cladding materials to

not-combustible materials, or request additional fire strategies. The goal of this analysis is to understand if an MTB's facade looks similar to the facade of a timber building, and to see if there are differences between the countries. The range of materials set are common cladding materials. As with previous categories, a last section "other" collects single cases materials or unspecified cladding.

- **Wood:** buildings can have wooden boards or shingles as part of their cladding. Some case-studies did not have the exterior wood treated and as time passed, the colour of the wood changed. In other case-studies, the wood was treated with different products or techniques.
- **Wood/metallic:** a different category was created in the case wooden cladding was used in combination with a consistent amount of metallic cladding. Often this solution is introduced to meet fire requirements.
- **Bricks:** another typical type of cladding used in the facade are bricks.
- **Curtain wall:** a curtain wall system is a facade cladding which can be composed of several materials. However, the majority of the case-studies have a glass curtain wall. This type of cladding is characterized by high transparency, allowing the timber to be visible from the outside if it is left exposed on the inside.
- **Metallic:** several metallic materials were collected in this category. These include zinc, aluminium, corten and others.
- **Plaster:** alternatively, the facade of the buildings can be plastered.

Figure 5.9: Facade examples

(a) Wood, (b) Wood/metallic, (c) Bricks, (d) Curtain wall, (e) Metallic, (f) Plaster, (g) Other

Source: VK Architects & Engineers, Bygg.no, Alex de Rijke, Tom Roe, Abaton, Martin Grabner, cetus Baudevelopment GmbH-Thomas Lerch

- **Others:** less typical or single-appearing materials were collected together in this category. These materials are cement cladding, ceramic and stone. When a material was not clear, it also belonged to this category.

Interior Timber Exposure

The benefits that a natural environment can have on the well-being of its users is well known, as Section 2.5 described. The choice of leaving some or all of the structural elements left exposed depends on both the regulations of each country, and on the design team. Exposing timber elements in most cases implies a fire strategy based on timber charring, or the presence of sprinklers.

- **All the elements:** when all elements are visible, or when all the post-and-beam structural elements and the ceiling are left exposed.
- **Ceiling:** when the EWPs are left visible only on the ceilings.
- **Columns and beams:** when only the post-and-beam structures are left visible, but not the floor slabs.
- **Walls:** when only some or all interior timber walls are left visible inside.
- **None:** this category refers to all the projects which do not show any timber structural elements inside. In this case, the structural elements are all enveloped with gypsum boards.

Figure 5.10: Examples of timber exposure indoors

a) All the elements, (b) Ceiling, (c) Columns and beams, (d) Walls, (e) None

Source: Nordic Lofts, Teknoring, Didier Boy de la Tour, Mansfield College Oxford, Michael Elkan and Acton Ostry Architects

Building Volume

Kuzmanovska et al. (2018) has already made some distinctions regarding the architectural massing of the selected case-studies of their studies. The goal of this analysis is to understand if MTBs have complex volumes and plans, or if they have regular shapes.

- **Regular:** when the building has a simple volume, which is the simple extrusion of the plan.
- **Pitched Roof:** when the volume of the building is characterised by a simple volume with a characteristic or evident pitched roof.
- **Varying heights:** when the volume of the building is regular, but it gradually thins as it gets taller.
- **Irregular:** when the volume of the building is more complex and the vertical volume does not match the ground floor's plan.

Figure 5.11: Building volumes examples
(a) Regular, (b) Pitched Roof, (c) Varying heights, (d) Irregular
Source: Weissenseer, Wingårdh, Sergio Grazia, WoodTek

5.3 Design Analysis of the Case-Studies

This study, performed across multiple countries and multiple case-studies, has been laid out in this section to explore and compare how MTBs differ between each country according to the analysis survey categories. The 197 case-studies have been analysed by dividing them into 15 groups of countries. The countries follow a continental order (Europe, North America, Other) and then alphabetical order. The section "Benelux" includes both Belgian and Dutch case-studies, whereas "Other countries" includes Chile, New Zealand and Taiwan. Every section is provided with a map which shows the location of the case-studies, their structural system and their height. A table with all the data collected can be found at the end of each section.

5.3.1 Austria

see Appendix pages 305-320

Figure 5.12: Location, structure and number of storeys of the case-studies in Austria

Sixteen Austrian case-studies were selected, and were completed between 2004 and 2019. In total, in Austria there are 24 MTBs, with projects like *Hummelkaserne* and *Mühlweg Bauteil C* which have four buildings each. *Reininghaus Sud* and *Holzwohnbauten im Dragoner-Quartier* are both composed of several buildings, but only two (for each project) met the height criteria of the survey. As Figure 5.12 shows, nearly half of the case-studies were completed in Vienna, with the others realised in other cities of the country. The Austrian case-studies are more mid-rise than high-rise, with an average height of six storeys. *HoHo Wien* is the exception with its twenty-four storeys, which also makes it the largest building with around 25,000 m^2 (Woschitz, 2019). The total area of the Austrian case studies is 111,500 square meters.

Regarding the structural design, all the projects have hybrid timber-concrete structures. *BMW-Hotel Alpenhof* and *Seniorenwohnheim Hallein* have a 3D modular timber-concrete structure (Mayo, 2015) (proHolz, n.d.). These projects have podiums and cores made of concrete and their 3D modules made of CLT were built off-site. Upon completion, they were transported with trucks onto the building-site and stacked on the top of the concrete podium.

Life Cycle Tower, *Illwerke Zentrum Montafon*, *HoHo Next*, and *HoHo Wien* have a post-and-beam timber-concrete structure. Only *Life Cycle Tower* has a concrete podium, while the other projects all have concrete cores. *Life Cycle Tower* and *Illwerke Zentrum Montafon* have a similar constructive system where the columns of the buildings are pre-assembled together with the facade, and the floor system is made of glulam-concrete slabs (also pre-assembled together) (Green and Taggart, 2017) (Kaufmann et al., 2018). The structural system of *Illwerke Zentrum Montafon* is represented in Figure 5.13, as its glulam-concrete floor slabs. This type of kit-structure is similar to the one used in *HoHo Next* and *HoHo Wien* (see Figure 5.14). Both of the projects are part of the *HoHo* development, which is divided in two separate buildings: *HoHo Next*, was completed in 2018 and *HoHo Wien*, was completed in 2019. Both buildings have the same structural system and identical interior timber exposure, but they differ in height, volume and facade cladding. All these structural elements are visible inside and both the projects were built with a high-level of

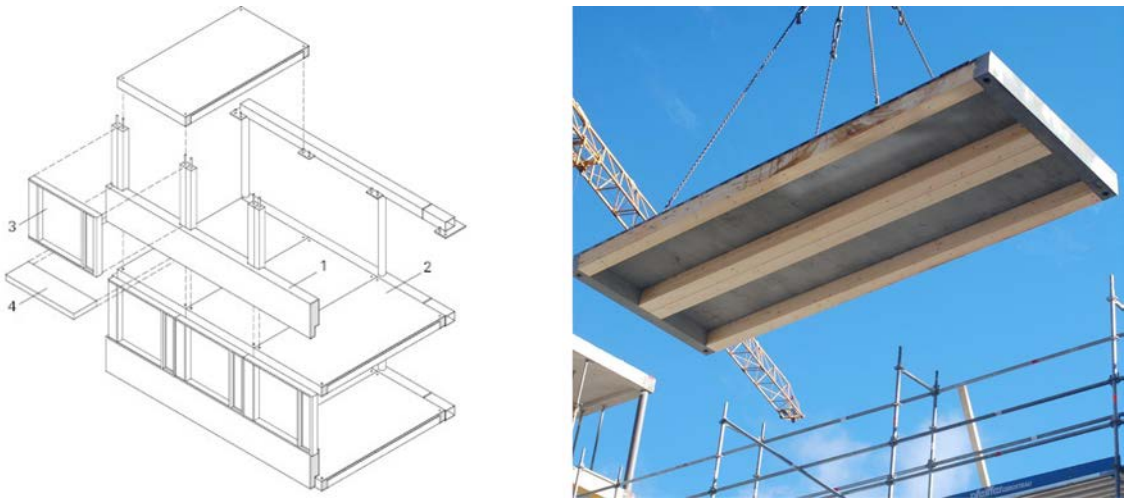

Figure 5.13: Schematic assembly of *Illwerke Zentrum Montafon* and its floor slabs

Source: dbz

pre-assembly: columns arrived at the building site with the necessary steel connection, and the floor slabs were already placed with the concrete layer on the top of the CLT slabs. Their LLRS is composed of a concrete core which is connected to the hybrid CLT-concrete floor slabs. A concrete precast beam on the edge of the building connects both the columns and the floor slabs (Woschitz, 2019). In this detail *HoHo Next* and *HoHo Wien* differ from *Life Cycle Tower* and *Illwerke Zentrum Montafon*. In the last two projects, the concrete precast beam is included in the floor slabs which are directly connected to the columns. While *HoHo Wien* is composed of three different volumes in heights and covered by a cement-base facade material, *HoHo Next* is instead fully enveloped with wooden boards. In both the buildings, special bigger glassed parts in different floors show the glulam columns from the outside. No loggias or balconies are designed but the different heights of the volumes create usable terraces (Woschitz, 2019) (Lignum, 2020).

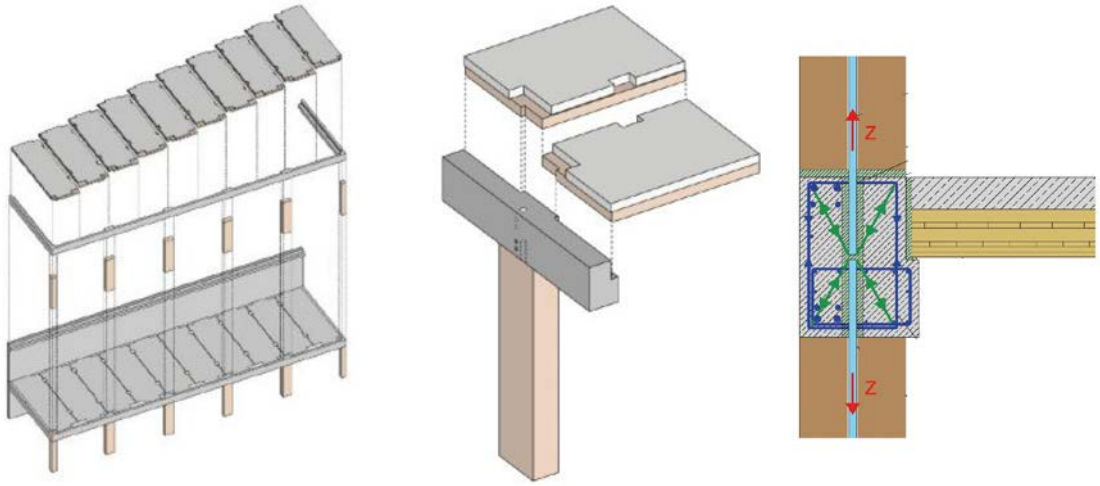

Figure 5.14: HoHo constructive system and detail of the concrete edge beam

Source: Woschitz Group and Woschitz and Zotter (2017)

All the other ten case-studies have a panelised timber-concrete structure (Falk, 2005) (Untertrifaller, 2010) (proHolz, 2020*b*) (Gruber, 2015) (Nextroom, 2017*a*) (Hagleitner, 2017) (einszueins, n.d.) (Leeb, 2020). Six case-studies have both podium and core made of concrete, whereas four projects have only a concrete core. CLT was the preferred type of walls and floor slabs. The technical solutions varied according to the type of prefabrication and floor slabs used. The external CLT panels of the facade of *Hummelkaserne* were pre-assembled off-site with the windows and wood cladding having been already integrated, while the hybrid CLT-concrete floor slabs of *Gesundheits.Quartiers* and *Gleis 21* were pre-assembled off-site. The facades of *Gesundheits.Quartiers* were pre-assembled as well, and only the windows had to be mounted in the building site (Pendlmayr, 2020).

All cores in the projects were built with reinforced concrete. Half of the case-studies have also the ground floor made of reinforced concrete, whereas the other half has it down to the foundation level. The last four projects *Hoho Next*, *Hoho Wien*, *Gesundheits.Quartiers*, *Gleis 21* all have CLT-concrete floor slabs. The older project *Wagramerstrasse* has also CLT-concrete floors but the layer of concrete was poured on site (Schluder, 2012). *Life Cycle Tower*, and *Illwerke Zentrum Montafon* have hybrid glulam-concrete floors. All the other nine projects use CLT panels for the floor slabs.

Nine of the Austrian case-studies are residential buildings, of which three are social housing projects and one is a co-housing project. *Hoho Wien* has a mixed (residential and others functions) program. The remaining projects have other heterogeneous programs. *Life Cycle Tower*, *Illwerke Zentrum Montafon*, and *Hoho Next* are office buildings. The other three case-studies are a hotel, a senior living center and a student housing building. The majority of the buildings have wooden facades. Four projects have a plaster cladding, three have metallic cladding and two have a cement based cladding. Four case-studies have all the structural timber surfaces encapsulated with gypsum boards. Of the remaining case-studies, five have all the elements visible and six have the ceilings visible (besides some secondary columns and beams). The architectural mass of the projects is always regular, with rectangular, square or L-shaped plans.

Table 5.1: List of the Austrian case-studies and their main design data points

Project (name)	(image)	Storeys (number)	Timber Storeys (number)	Strucutral system (logo)	(category)	Core (material)	Floor Slabs (material)	Total Built Surface (m2)	Program (type)	Facade cladding (material)	Structural timber exposure (category)
Spöttlgasse		5	4		Panelised timber-concrete (podium-core)	Concrete	CLT	5300	Residential - Social Housing	Plaster	None
Mühlweg Bauteil C		5	5		Panelised timber-concrete (core)	Concrete	CLT	6750	Residential - Social Housing	Plaster	None
BMW-Hotel Alpenhof		5	3		3D Modular timber-concrete (podium-core)	Concrete	CLT	8175	Hotel	Metal	All the surfaces
Life Cycle Tower		8	7		Post-and-Beam timber-concrete (podium-core)	Concrete	Glulam-concrete	2300	Office	Metal	All the surfaces
Senioren wohnheim Hallein		5	4		3D Modular timber-concrete (podium-core)	Concrete	CLT	10218	Senior living	Metal	Ceiling
Wagramerstrasse		7	6		Panelised timber-concrete (podium-core)	Concrete	CLT-concrete	6254	Residential - Social Housing	Plaster	None
Illwerke Zentrum Montafon		5	5		Post-and-Beam timber-concrete (core)	Concrete	Glulam-concrete	11500	Office	Wood	All the surfaces
Reininghaus Sud		5	4		Panelised timber-concrete (podium-core)	Concrete	CLT	4000	Residential	Plaster	Ceiling
Holzwohnbau Rosenstraße		5	4		Panelised timber-concrete (podium-core)	Concrete	CLT	2265	Residential	Cement based	Ceiling
Hummelkaserne		6	6		Panelised timber-concrete (core)	Concrete	CLT	9306	Residential	Wood	None
Mineroom		5	5		Panelised timber-concrete (core)	Concrete	CLT	5274	Student Housing	Wood	Ceiling
Holzwohnbauten im Dragoner-Quartier		6	6		Panelised timber-concrete (core)	Concrete	CLT	1875	Residential	Wood	Ceiling
Hoho Next		6	6		Post-and-Beam timber-concrete (core)	Concrete	CLT-concrete	5686	Office	Wood	All the surfaces
Gesundheits. Quartiers		7	6		Panelised timber-concrete (podium-core)	Concrete	CLT-concrete	3585	Residential	Wood	Ceiling
Gleis 21		6	5		Panelised timber-concrete (podium-core)	Concrete	CLT-concrete	3992	Residential - Co-housing	Wood	All the surfaces
Hoho Wien		24	24		Post-and-Beam timber-concrete (core)	Concrete	CLT-concrete	25000	Mixed Use (residential-other)	Cement based	All the surfaces

5.3.2 Benelux

see Appendix pages 322-326

Figure 5.15: Location, structure and number of storeys of the case-studies in Benelux

Five case-studies have been found in the Benelux region, two built in Belgium and three built in the Netherlands. The projects were all built between 2008 and 2019, and they include six buildings. In Belgium there are only mid-rise case-studies, whereas in the Netherlands, the case-studies are five, seven and nine storeys (see Figure 5.16). The total square metres built is around 28,000 m^2, with *Hotel Jakarta* as the largest building, covering 16,500 m^2 (Koller, 2018).

The projects have different structures. Both of the Belgian case-studies use CLT walls and floors, but they differ in the overall concept. While *Les Closières* has a panelised all-timber structure with CLT used also in the core of the project, *Kietude* has instead a panelised timber-concrete-steel system. The building has a concrete core and steel beams used at the external edge of the floors, which are designed to support the GLRS formed by CLT floor slabs (Ernest, 2018) (Ney&Partners, 2020). Both projects were designed with additional internal columns or beams made of glulam. None of the projects have a podium because their timber structure begins directly at the ground floor level. The Dutch case-studies differ from one another too. *Malmo Hus* has a panelised all-timber structure (van Egmond, 2011), whereas *Patch 22* has a post-and-beam timber-concrete structure (Thematic Design, n.d.) and *Hotel Jakarta* is formed by 3D modular timber-concrete elements (Koller, 2018). Figure 5.16 shows the 3D modules of the project which are formed by a concrete floor and CLT walls.

The cores of *Kietude*, *Patch 22*, and *Hotel Jakarta* are made of concrete, whereas in *Malmo Hus* they do not have any structural function (van Egmond, 2011). *Les Closières* has a CLT core. The floor slabs of the projects are all different. LVL box-elements were used in *Malmo Hus*, a glulam frame supporting concrete floor slabs was designed in *Patch 22*, and in *Hotel Jakarta* the modules have a concrete floor and a CLT ceiling. By stacking the modules on top of each other,

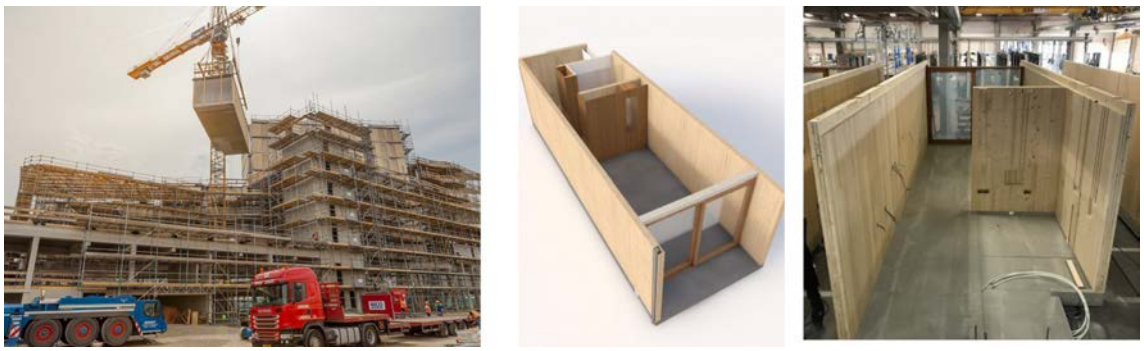

Figure 5.16: 3D modules of *Hotel Jakarta*

Source: Ursem Bouw

the resulting floor slabs are a combination of concrete-CLT floors. All the Dutch projects have a ground floor podium made of reinforced concrete, whereas none was designed in the Belgian ones.

Both Belgian case-studies, *Malmo Hus*, and *Patch 22* are residential buildings. *Hotel Jakarta* is a hotel. Three case-studies have a wooden facade, whereas *Hotel Jakarta* has a curtain wall with a glass and metallic cladding. *Kietude* has a plaster facade. Timber is visible inside all the projects, except in *Malmo Hus* and is left visible in some walls in *Kietude*. From a composition point of view, both *Kietude* and *Patch 22* have a sculptured facade whereas *Les Closieres*, is composed by a regular plan with volumes of different heights. *Malmo Hus* and *Hotel Jakarta* have simple volumes with the latter having a triangular plan.

Table 5.2: List of the Benelux case-studies and their main design data points

Project *(name)*	*(image)*	**Storeys** *(number)*	**Timber Storeys** *(number)*	**Strucutral system** *(logo)*	*(category)*	**Core** *(material)*	**Floor Slabs** *(material)*	**Total Built Surface** *(m2)*	**Program** *(type)*	**Facade cladding** *(material)*	**Structural timber exposure** *(category)*
Malmo Hus		5	4		Panelised timber-concrete (podium)	CLT	LVL	5400	Residential	Wood	None
Les Closières		5	5		Panelised all-timber	CLT	CLT	800	Residential	Wood	All the surfaces
Patch 22		7	6		Post-and-Beam timber-concrete (podium-core)	Concrete	Glulam-concrete	5400	Residential	Wood	All the surfaces
Kietude		6	6		Panelised timber-concrete-steel (core-steel beams)	Concrete	CLT	720	Residential	Plaster	Walls
Hotel Jakarta		9	8		3D Modular timber-concrete (podium-core)	Concrete	CLT-concrete	16500	Hotel	Curtain wall	All the surfaces

5.3.3 Finland

see Appendix pages 328-337

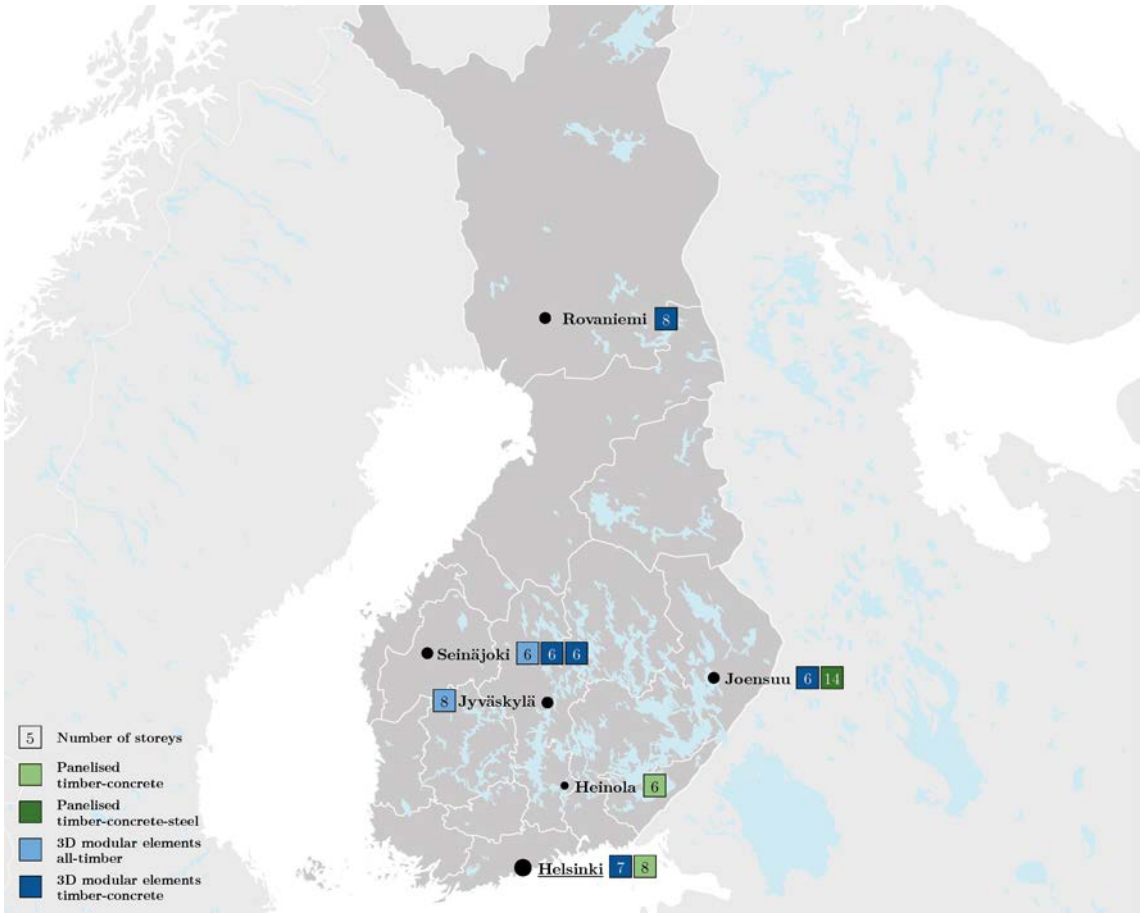

Figure 5.17: Location, structure and number of storeys of the case-studies in Finland

Ten case-studies were selected in Finland and were completed between 2012 and 2019. In reality, they are composed of 15 buildings: *Eskolantie* and *Puukuokka* are both composed of three buildings each, and *Wood City* is composed of two buildings. The majority of the case-studies are six-storeys high. Three case-studies are high-rise buildings: two buildings *Puukuokka* and *Das Kelo* are eight storeys tall. The tallest project is *Lighthouse Joensuu*, which is fourteen-storey tall. The three buildings of *Eskolantie* make the project around 9,800 m^2, and it is the largest of the Finnish case-studies. The total amount of square meters of all the projects is around 50,000 m^2. The projects are evenly distributed throughout the country with several of them built in the West city of Seinäjoki (see Figure 5.17).

Finland is the only country in which the majority of the projects have a 3D modular element structure (Mikkola, 2014) (PuuInfo, 2020*c*). Seven case-studies were built with 3D modules, and only *Puukuokka* (Green and Taggart, 2017) (Kaufmann et al., 2018) and *Mäihä* (PEFC, 2016) are all-timber buildings, whereas the rest are hybrid timber-concrete structures with a concrete podium (PuuInfo, 2020*a*) (Woodarchitecture, 2020) (PuuInfo, 2020*c*) (Mikkola, 2014). The 3D modules were mostly pre-assembled off-site with many arriving on-site already mounted (cladding, windows). The elements were assembled in a warehouse or in a plot near the building site. Often

Figure 5.18: Assembly at the building site of *Pihapetäjä* 3D modules

Source: Puuinfo and Joensuun Pihapetaja

the buildings are also covered by a protective tent which makes the assembly process easier by protecting both the elements and the workers. The modules are not always closed on all the four sides, and flats can be composed by several modules, one adjacent to another, with some sides kept open to create a unique space (see Figure 5.18). Besides its 3D modular structure, *Seinäjoen Tuohi* also has bathrooms modules incorporated (Lakea, 2020).

Puumera is the only case-study with a panelised timber-concrete structure with a concrete core and a glulam-concrete floor slabs whereas *Wood City* has a panelised timber-concrete structure with only a concrete podium (Projektiuutiset, 2011) (Hernández, 2018). The tallest MTB of Finland is *Lighthouse Joensuu* and it is a student residence with 117 beds. The building is fourteen storeys tall and has a panelised timber-concrete-steel structure. The LLRS is formed by an LVL core and LVL shear walls with special tie-down systems made of steel (Keskisalo, 2018). These systems are anchored to the ground floor of the building which is made of reinforced concrete. The GLRS is formed by CLT floors and LVL load bearing walls (Keskisalo, 2018).

Apart *Puumera*, all the other projects have a EWP-based core. The two case-studies *Lighthouse Joensuu* and *Wood City* have an LVL core, whereas the rest have a CLT core, mostly made as a 3D element. The majority of the case-studies have a reinforced concrete podium. In four projects the timber structure begins directly at the ground floor level. CLT is also the most common floor slab material. In the project *Wood City*, LVL floor slabs were used (Hernández, 2018).

All the projects are residential buildings, except *Lighthouse Joensuu* and *Das Kelo*, which are student residences. Except for the tallest case-study, all the projects have a wooden facade, with *Lighthouse Joensuu* having a stone tiles facade (Keskisalo, 2018). The majority of the projects leave visible the structural timber on the ceilings of their rooms. Four projects envelope their entire structure in gypsum boards. The majority of the buildings have a simple volume with or without a pitched roof.

Table 5.3: List of the Finnish case-studies and their main design data points

Project (name)	(image)	Storeys (number)	Timber Storeys (number)	Strucutral system (logo)	(category)	Core (material)	Floor Slabs (material)	Total Built Surface (m2)	Program (type)	Facade cladding (material)	Structural timber exposure (category)
Puumera		5	5		Panelised timber-concrete (core)	Concrete	Glulam-concrete	1915	Residential	Wood	Ceiling
Lintuviita		6	5		3D Modular timber-concrete (podium)	CLT	CLT	3100	Residential	Wood	None
Eskolantie		7	6		3D Modular timber-concrete (podium)	CLT	CLT	9876	Residential	Wood	None
Puukuokka		8	8		3D Modular element all-timber	CLT	CLT	8950	Residential	Wood	Ceiling
Mäihä		6	6		3D Modular element all-timber	CLT	CLT	2348	Residential	Wood	Ceiling
Pihapetäjä		6	5		3D Modular timber-concrete (podium)	CLT	CLT	2969	Residential	Wood	Ceiling
Lighthouse Joensuu		14	13		Panelised timber-concrete-steel (podium-steel rods)	LVL	CLT	4800	Student Housing	Other	None
Wood City		8	7		Panelised timber-concrete (podium)	LVL	LVL	8200	Residential	Wood	None
DAS Kelo		8	7		3D Modular timber-concrete (podium)	CLT	CLT	4583	Student Housing	Wood	Ceiling
Seinäjoen Tuohi		6	5		3D Modular timber-concrete (podium)	CLT	CLT	2541	Residential	Wood	Ceiling

5.3.4 France

see Appendix pages 339-357

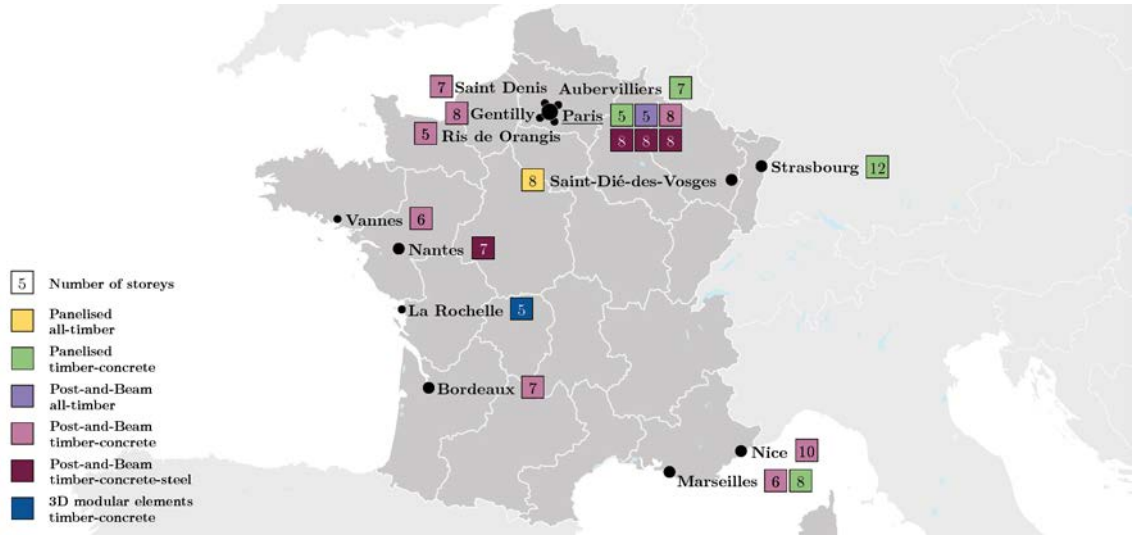

Figure 5.19: Location, structure and number of storeys of the case-studies in France

Nineteen case-studies were completed in France. They were all built between 2013 and 2019. During the last three years of the research, eleven case-studies have been completed, making the construction of MTBs in France a recent (but growing) practice. All the French projects are composed of one building and ten of them are mid-rise projects. Nine projects range between eight and twelve-storeys. In total, the case-studies are 135,400 m^2. The largest developments were *Pulse* and *Green Office® Enjoy*: the first one is 28,500 m^2 and the second is 17,400 m^2. A consistent number of case-studies were completed in the capital of Paris (or around it), meanwhile several projects were built along the Atlantic coast (see Figure 5.19). The remaining projects are located in the South and East regions of the country.

Only two case-studies have an all-timber structure. *Residences J.Ferry* has a panelised and frame all-timber structure (Gruber, 2013), and *Bâtiment Max Weber* has a post-and-beam all-timber structure (Fuchs and Mussier, 2019). The rest of the projects have variations with timber-concrete or timber-concrete-steel. The majority of them have a post-and-beam structure. Other eight projects have the frame connected to concrete cores and anchored to a concrete podium. *Opalia*, *Green Office® Enjoy*, *Kibori*, *Pont de Flandres Batiment 007* all have a timber-concrete-steel structure with different variations. *Opalia* has concrete cores with steel beams which are used mainly on the external edge of each floor (SEMAPA, 2020). *Pont de Flandres Batiment 007* has a similar system, but it rises on the top of a concrete podium (Woodsurfer, 2017). *Green Office® Enjoy* and *Kibori* have a concrete podium and core with steel braces which stiffen the structure of the buildings (Ware, 2018). The 17,400 m^2 office building *Green Office® Enjoy* is a particular example of hybrid combinations in MTBs. The building is eight storeys high, and its first two storeys form the concrete podium on which the glulam frame of the building is anchored. The stiffening is provided by concrete cores and steel bracing beams which run throughout the facade (Vaillé and Brisebourg, 2018). A part of the last top storey is made of steel.

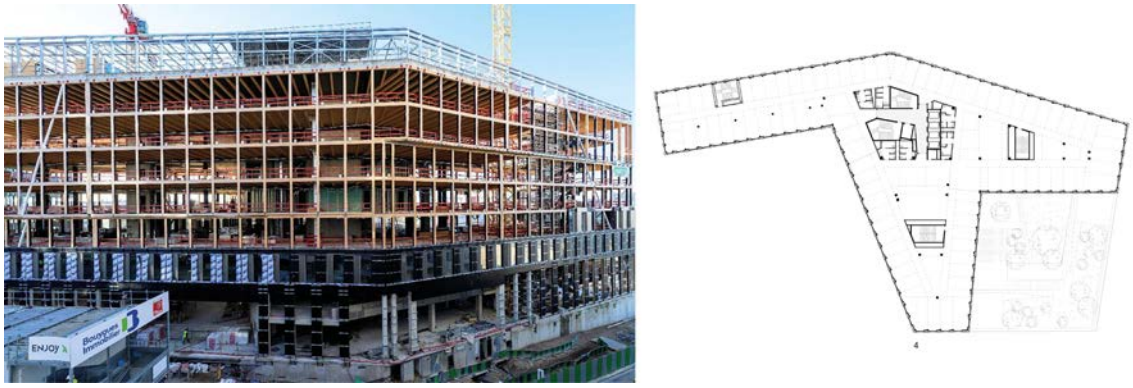

Figure 5.20: *Green Office® Enjoy* under construction and its plan

Source: L. Zylberman and Baumschlager Eberle Architekten

The GLRS is composed of the glulam frame and the CLT floor slabs. In some parts of the building, CLT-glulam floors were also used. Columns and beams are visible inside the office spaces. The entire volume is enveloped by a grey metallic cladding and high regular windows give rhythm to the facade. Additionally, the plan of the building is irregular (see Figure 5.20), and it has a central core with three volumes which depart from it.

The most numerous structural category is the post-and-beam timber-concrete with both podium and core made of concrete. *Maison de l'Inde* (Lipsky and Gaujard, 2013), *Ywood Les Docks Libres* (Bouquet, 2015), *DDTM* (AIA Life Designers, n.d.), *Quai de la Borde* (Wilmotte Architectes, n.d.), *Perspective* (Nicolas Laisné Architectes, n.d.), *Jo&Joe* (Viguier, n.d.), *Palazzo Nice Meridia* (Bouquet and Lehmann, 2018) (Lignum, 2020), and *Pulse* (Bruchon et al., 2019) are all projects belonging to this category. The floor slabs are most of the time made of CLT, with few projects using different materials.

Rue des Ardennes, *Lucien Cornil Student Residence*, *Pop-Up*, and *Sensations* are all projects based on a panelised timber-concrete concept, each one with a different variation (in order): timber-concrete podium (Chroniques-architecture, 2016), core (Cervantes, 2018), podium (Divisare, 2017), and podium (with an interior frame) (Stuerwald, 2018). Only *Crous Jean Jouzel* has a 3D modular timber element structure on the top of a concrete podium (Ingenieriebois, n.d.). The 3D modules were delivered with the structural parts already assembled, but the other layers were placed once the structure was completed.

The vast majority of the buildings have a concrete core. CLT cores are present in the both the all-timber projects *Residences J.Ferry* and *Bâtiment Max Weber*. CLT cores were also designed in *Crous Jean Jouzel*, *Rue des Ardennes*, and *Sensations*. The majority of the case-studies have a concrete podium, with only four case-studies having the timber structure start directly at the ground floor level. The most common material for the floor slabs is CLT. *Bâtiment Max Weber*, *DDTM*, and *Pont de Flandres Batiment 007* have glulam-concrete floor slabs. Three other projects *Maison de l'Inde*, *Perspective*, and *Pulse* have respectively glulam, LVL and CLT-glulam floors. The case-studies have heterogeneous programs: if the majority of them are office buildings (nine projects), there are also five residential case-studies (one of which is a social housing building), three student residences, one hotel, and one education building. The choice of the exterior facade is

also heterogeneous: five case-studies have metal cladding, five case-studies a wooden and metallic cladding, four buildings have a wood cladding and the remaining four case-studies have all different cladding, which are terra cotta, plaster, curtain walls and stone. Fourteen projects expose some parts of the structure, meanwhile four cases are fully encapsulated and most of the buildings have simple volumes.

Table 5.4: List of the French case-studies and their main design data points

Project (name)	(image)	Storeys (number)	Timber Storeys (number)	Strucutral system (logo)	(category)	Core (material)	Floor Slabs (material)	Total Built Surface (m2)	Program (type)	Facade cladding (material)	Structural timber exposure (category)
Maison de l'Inde		8	7		Post-and-Beam timber-concrete (podium-core)	Concrete	Glulam	2860	Student Housing	Wood	None
Crous Jean Jouzel		5	4		3D Modular timber-concrete (podium)	CLT	CLT	3700	Student Housing	Metal	Ceiling
Residences J.Ferry		8	8		Panelised all-timber and frame	CLT	CLT	2702	Residential	Other	All the surfaces
Ywood Les Docks Libres		6	5		Post-and-Beam timber-concrete (podium-core)	Concrete	CLT	3637	Office	Wood	All the surfaces
Bâtiment Max Weber		5	5		Post-and-Beam all-timber	CLT	Glulam-concrete	4904	Education	Metal	All the surfaces
DDTM		6	5		Post-and-Beam timber-concrete (podium-core)	Concrete	Glulam-concrete	6779	Office	Wood / Metal	Columns and beams
Quai de la Borde		5	4		Post-and-Beam timber-concrete (podium-core)	Concrete	CLT	8800	Residential	Plaster	None
Rue des Ardennes		5	4		Panelised timber-concrete (podium)	CLT	CLT	1000	Residential	Wood	None
Lucien Cornil Student Residence		8	8		Panelised timber-concrete (core)	Concrete	CLT	4352	Student Housing	Wood / Metal	All the surfaces
Opalia		8	8		Post-and-Beam timber-concrete-steel (core-steel beams)	Concrete	CLT	6500	Office	Wood	All the surfaces
Green Office® Enjoy		8	5		Post-and-Beam timber-concrete-steel (podium-core-steel bracing)	Concrete	CLT	17400	Office	Metal	Columns and beams
Kibori		7	6		Post-and-Beam timber-concrete-steel (podium-core-steel bracing)	Concrete	CLT	4620	Office	Metal	All the surfaces
Perspective		7	6		Post-and-Beam timber-concrete (podium-core)	Concrete	LVL-concrete	5156	Office	Wood / Metal	Columns and beams
Jo&Joe		8	7		Post-and-Beam timber-concrete (podium-core)	Concrete	CLT	7000	Hotel	Metal	All the surfaces
Palazzo Nice Meridia		10	9		Post-and-Beam timber-concrete (podium-core)	Concrete	CLT	7885	Office	Metal	All the surfaces
Pont de Flandres Batiment 007		8	7		Post-and-Beam timber-concrete-steel (podium-core-steel beams)	Concrete	Glulam-concrete	8577	Office	Curtain wall	Columns and beams
Pop-Up		7	6		Panelised timber-concrete (podium-core)	Concrete	CLT	1900	Residential - Co-housing	Other	None
Pulse		7	6		Post-and-Beam timber-concrete (podium-core)	Concrete	CLT-glulam	28450	Office	Wood / Metal	All the surfaces
Sensations		12	11		Panelised timber-concrete (podium and frame)	CLT	CLT	9146	Residential	Wood / Metal	None

5.3.5 Germany

see Appendix pages 359-377

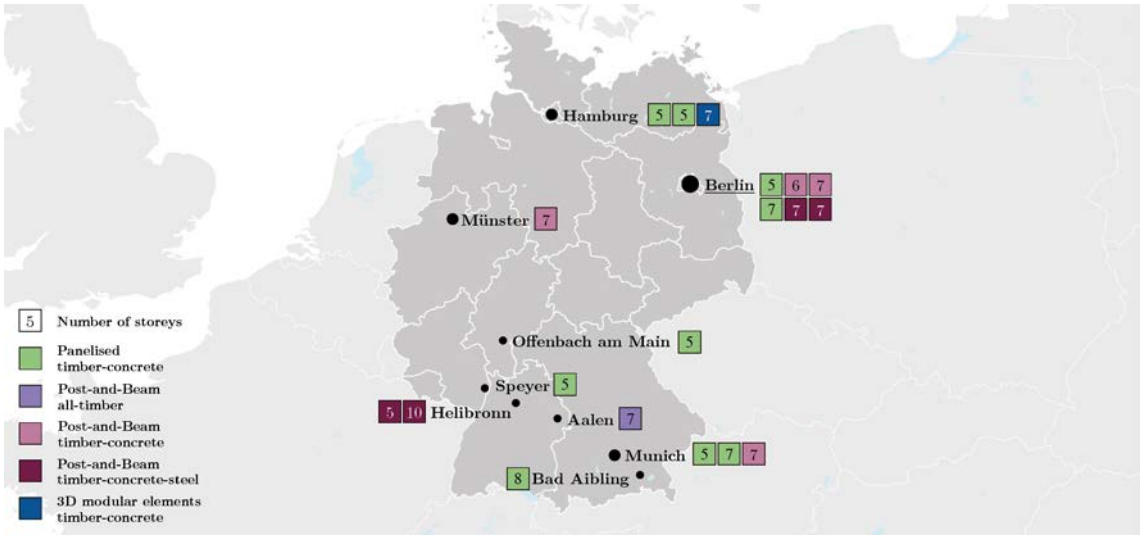

Figure 5.21: Location, structure and number of storeys of the case-studies in Germany

Nineteen case-studies were selected in Germany. They were completed between 2007 and 2019. Nearly half of them (nine case-studies) were completed in the last three years, showing that the practice of MTBs is also a recent implementation in Germany. In these case studies, there are twenty-five actual buildings since *Prenzlauer Berg* and *WA14 West* are composed of three and four buildings respectively. By the comparison of their height, most of the case-studies in Germany are mid-rise projects. The only high-rise buildings are *Holz8* and *Skaio*. The 13,510 m^2 of *Woodie* makes the student housing building the largest development carried out in Germany as of 2019 (Kaufmann, 2018). Considered all together, the German projects consist of around 95,000 m^2. The case-studies are distributed in the North, West and South cities of the country. The capital Berlin has six case-studies, which is the highest amount that a city has in Germany. Second are Hamburg and Munich which have three case-studies each.

The vast majority of the case-studies are hybrid buildings: only *Kampa K8* is a post-and-beam all-timber structure (Kaufmann et al., 2018). *Woodie* is the only 3D modular timber-concrete project (Lignum, 2019*b*). The building is composed of modules 20 m^2 each, which were assembled off-site and transported with trucks (Bartenschlag, 2018). The rest of the case-studies are evenly divided between panelised timber-concrete and hybrid post-and-beam structures. *Holz8* (Mayo, 2015), *WoodCube* (Green and Taggart, 2017), *Nachverdichtung Speyer* (Züblin Timber, n.d.), and *Walden 48* (Rubner Holzbau, n.d.*b*) all have concrete cores. *Prenzlauer Berg* (Jacob-Freitag, 2010), *Wälderhaus* (Andreas Heller Architects, n.d.), *Wohnen Offenbach* (Seen, 2019), and *WA 15 West* (Huber, 2019) have both a concrete podium and cores. *Dantebad* has a concrete podium, and the rest of the structure is made of CLT shear walls (Herrmann, 2018) (Kaufmann et al., 2018).

Similar heterogeneity can be found in the post-and-beam examples. *Kampa K8* have a post-and-beam all-timber structure (Kaufmann et al., 2018). *3XGrün* (Ballhausen, 2012), *H7* (Hein et al.,

2016), and *WA14 West* (Jacob-Freitag, 2010) have a post-and-beam timber-concrete structure with concrete podiums and cores. The core of *H7* is connected to the glulam columns in the facade, with a hybrid glulam-concrete floor (Hein et al., 2016). Both the facade and the floor slabs were pre-assembled before they arrived in the building-site. *Lynarstrasse Berlin* (Seen, 2019) has only the podium made of concrete. The four projects *E3* (Käpplinger, 2009), *C13* (Kaufmann et al., 2018), *Famju* (Kaden+Lager Architeckten, n.d.) and *Skaio* (Kaden, 2018) (Lignum, 2020) have a similar post-and-beam timber-concrete-steel system, in which a glulam frame is connected to a lateral or central concrete core. The particularity of these buildings is the use of a steel beam on the external edge of the structure (see Figure 5.22). Additional stiffening can be provided by steel bracing in the facade like in *E3* (Kaufmann et al., 2018).

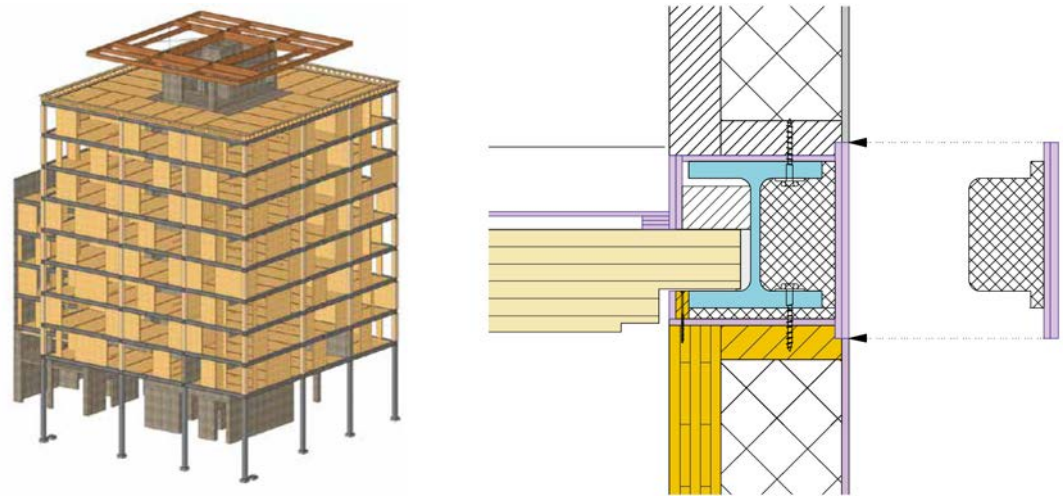

Figure 5.22: *Skaio*'s structure and detail of the steel edge beam

Source: Kaden-Lager Architekten

In the German case-studies, most of the time the core is made of concrete, and only three buildings have a CLT core. The majority of the projects also have the ground floor made of reinforced concrete and five case-studies begin directly at the ground floor level. CLT and CLT-based floors are by far the most utilised in the case-studies. Four projects have a hybrid CLT-concrete floor system. *H7* has hybrid glulam-concrete floor slabs. *E3* and *C13* utilises DLT and DLT-concrete floors. Glulam is the only material used for columns and beams.

Most of the German projects are residential. Five projects in particular are co-housing, and four are social housing. Five projects are normal residential buildings, and *Holz8*, and *C13* have both a mixed program residential-office. The remaining four projects have a heterogeneous program: *Wälderhaus* is a hotel, *Kampa K8* and *H7* are offices and *Woodie* is a student housing. Ten case-studies have a wooden facade and Walden 48 has a mixed wooden-metallic facade. Of the remaining projects, five have a plaster facade and three have a metallic facade. The majority of the buildings have few structural elements exposed. When an element was chosen to be exposed, in most cases, it was the ceiling. Four case-studies do not have any visible timber structural element, whereas only three case-studies have all the elements fully visible. All the German projects are simple geometries

with simple extruded volumes. Some have varying volumes, but the vast majority are cubic or rectangular buildings. *Woodie* has a more complex plan in comparison to the other projects.

Table 5.5: List of the German case-studies and their main design data points

Project *(name)*	*(image)*	Storeys *(number)*	Timber Storeys *(number)*	Strucutral system *(logo)*	*(category)*	Core *(material)*	Floor Slabs *(material)*	Total Built Surface *(m2)*	Program *(type)*	Facade cladding *(material)*	Structural timber exposure *(category)*
E3		7	6		Post-and-Beam timber-concrete-steel (podium-core-steel beams)	Concrete	DLT	4670	Residential - Co-housing	Plaster	Ceiling
Prenzlauer Berg		5	4		Panelised timber-concrete (podium-core)	Concrete	CLT	5720	Residential - Co-housing	Plaster	None
Holz8		8	8		Panelised timber-concrete (core)	Concrete	CLT	1741	Mixed Use (residential-office)	Wood	Ceiling
3XGrün		6	5		Post-and-Beam timber-concrete (podium-core)	Concrete	CLT	2900	Residential - Co-housing	Metal	All the surfaces
Wälderhaus		5	3		Panelised timber-concrete (podium-core)	Concrete	CLT	5910	Hotel	Wood	All the surfaces
WoodCube		5	5		Panelised timber-concrete (core)	Concrete	CLT	1479	Residential	Wood	All the surfaces
C13		7	6		Post-and-Beam timber-concrete-steel (podium-core-steel beams)	Concrete	DLT-concrete	3682	Mixed Use (residential-office)	Plaster	Ceiling
Kampa K8		7	7		Post-and-Beam all-timber	CLT	CLT	3386	Office	Wood	All the surfaces
Nachverdichtung Speyer		5	5		Panelised timber-concrete (core)	Concrete	CLT	1185	Residential	Plaster	None
H7		7	6		Post-and-Beam timber-concrete (podium-core)	Concrete	Glulam-concrete	7000	Office	Metal	All the surfaces
Wohnen Offenbach		5	4		Panelised timber-concrete (podium-core)	Concrete	CLT-concrete	1578	Residential - Social Housing	Wood	None
Woodie		7	6		3D Modular timber-concrete (podium-core)	Concrete	CLT	13510	Student Housing	Wood	All the surfaces
Dantebad		5	4		Panelised timber-concrete (podium)	CLT	CLT	4630	Residential - Social Housing	Wood	Ceiling
Lynarstrasse Berlin		7	6		Post-and-Beam timber-concrete (podium)	CLT	CLT	7350	Residential - Social Housing	Wood	All the surfaces
Famju		5	4		Post-and-Beam timber-concrete-steel (podium-core-steel beams)	Concrete	CLT	1570	Residential	Plaster	None
Skaio		10	9		Post-and-Beam timber-concrete-steel (podium-core-steel beams)	Concrete	CLT	5685	Residential	Metal	All the surfaces
WA14 West		7	6		Post-and-Beam timber-concrete (podium-core)	Concrete	CLT-concrete	9215	Residential - Social Housing	Wood	None
WA15 West		7	6		Panelised timber-concrete (podium-core)	Concrete	CLT	6920	Residential - Social Housing	Wood	None
Walden 48		7	7		Panelised timber-concrete (core)	Concrete	CLT-concrete	7500	Residential - Co-housing	Wood / Metal	All the surfaces

5.3.6 Italy

see Appendix pages 379-391

Figure 5.23: Location, structure and number of storeys of the case-studies in Italy

The thirteen Italian case-studies were completed between 2012 and 2019. The actual number of buildings is twenty-one, with projects like *5 per 5+1* and *Cenni di Cambiamento* being composed of five and four buildings each. *Marina Verde* is formed by two buildings. Nearly all the projects are mid-rise. *Cenni di Cambiamento* is a high-rise and the largest project in Italy, taking up 30,325 m^2 of the total 78,000 m^2. The eight-storey project *Hotel Nautilus* is one of the tallest hotel buildings in the survey. The majority of the projects are located in Northern Italy, with few case-studies built in the central regions.

The prevailing structural category in Italy is the panelised structure which is adopted in two different variations: all-timber, and timber-concrete. *Cenni di Cambiamento* (Kaufmann et al., 2018), *Firenze Ex-Longinotti* (Vassallo and Pollari, 2018), *30 Wood House* (Ergodomus, n.d.), and *5 per 5+1* (Genero, 2019) are all built with an all-timber structure, with CLT (or timber frame) cores, walls, and floor slabs.

Hotel Nautilus (Gaudenzi, 2020), *Green Torino* (Green and Taggart, 2017), and *Social Housing Vado Ligure* (Gandelli Group, n.d.) have a concrete podium on which an all-timber CLT structure is erected. *Residence Alexander*, has a panelised CLT-concrete structure, with concrete core and CLT floor slabs and walls (Presutti, 2013). *Multipiano Coppito* and *Palazzina 5 piani* have both a concrete podium and core on which CLT walls and floor slabs are connected (Presutti, 2013) (Reynolds et al., 2015).

Besides the panelised structure, two projects, *Panorama Giustinelli* and *Marina Verde* have a post-and-beam timber-concrete structure with a reinforced concrete core, glulam frame and glulam floor slabs (Promo Legno, n.d.) (Rubner Holzbau, n.d.*a*). *Residenza Mayer* is the only 3D modular

timber-concrete structure with the 3D modules made of CLT and the cores of the building made of reinforced concrete (Essepi, n.d.). The all-timber modules were carried pre-assembled with a high level of prefabrication (see Figure 5.32).

Figure 5.24: Assembly and 3D modules of *Residenza Mayer*

Source: Alessandro Gadotti and Paolo Simeone

In the seven Italian case studies, the cores were made of CLT, whereas six were made of concrete. The majority of the projects begin their timber structure at ground floor level, and only five case-studies present a reinforced concrete podium. The floor slabs of the projects are mainly made of CLT panels, and only *Panorama Giustinelli* and *Marina Verde* have glulam-based floors.

The prevalent program typology is residential, with six residential buildings and four social housing projects. The other case-studies are the hotels (*Marina Verde* and *Hotel Nautilus*) and student housing Residenza Mayer). From an architectural perspective, the choice of the facade material is always plaster, excluding the project *Residenza Mayer*), which has a cement-based cladding. Most of the projects cover the structural timber surfaces with gypsum boards. Only the hotel rooms of *Hotel Nautilus* have the ceiling exposed (Gaudenzi, 2020). Some ceilings were left visible in *Cenni di Cambiamento*, but the overall strategy of the project was to envelop the CLT with gypsum boards. The majority of the Italian projects are enveloped by gypsum boards. The architectural mass of the buildings are mainly formed by simple volumes, with some other case-studies having pitched roofs.

Table 5.6: List of the Italian case-studies and their main design data points

Project (name)	(image)	Storeys (number)	Timber Storeys (number)	Strucutral system (logo)	(category)	Core (material)	Floor Slabs (material)	Total Built Surface (m2)	Program (type)	Facade cladding (material)	Structural timber exposure (category)
Residence Alexander		6	6		Panelised timber-concrete (core)	Concrete	CLT	4900	Residential	Plaster	None
Cenni di Cambiamento		9	9		Panelised all-timber	CLT	CLT	30325	Residential-Social Housing	Plaster	None
Panorama Giustinelli		7	7		Post-and-Beam timber-concrete (core)	Concrete	Glulam	4500	Residential	Plaster	None
Marina verde		7	7		Post-and-Beam timber-concrete (core)	Concrete	Glulam	14900	Hotel	Plaster	None
Multipiano Coppito		5	4		Panelised timber-concrete (podium-core)	Concrete	CLT	1200	Residential	Plaster	None
Firenze Ex-Longinotti		6	6		Panelised all-timber	CLT	CLT	5200	Residential - Social Housing	Plaster	None
Palazzina 5 piani		5	4		Panelised timber-concrete (podium-core)	Concrete	CLT	1350	Residential - Social Housing	Plaster	None
30 Wood House		6	6		Panelised all-timber	CLT	CLT	520	Residential	Plaster	None
Hotel Nautilus		8	7		Panelised timber-concrete (podium)	CLT	CLT	2458	Hotel	Plaster	Ceiling
Residenza Mayer		5	5		3D Modular timber-concrete (core)	Concrete	CLT	4350	Student Housing	Cement based	None
5 per 5+1		5	5		Panelised all-timber	CLT	CLT	5500	Residential - Social Housing	Plaster	None
GreenTorino		7	6		Panelised timber-concrete (podium)	CLT	CLT	930	Residential	Plaster	None
Social Housing Vado Ligure		5	4		Panelised timber-concrete (podium)	CLT	CLT	1750	Residential - Social Housing	Plaster	n/a

5.3.7 Norway

see Appendix pages 394-410

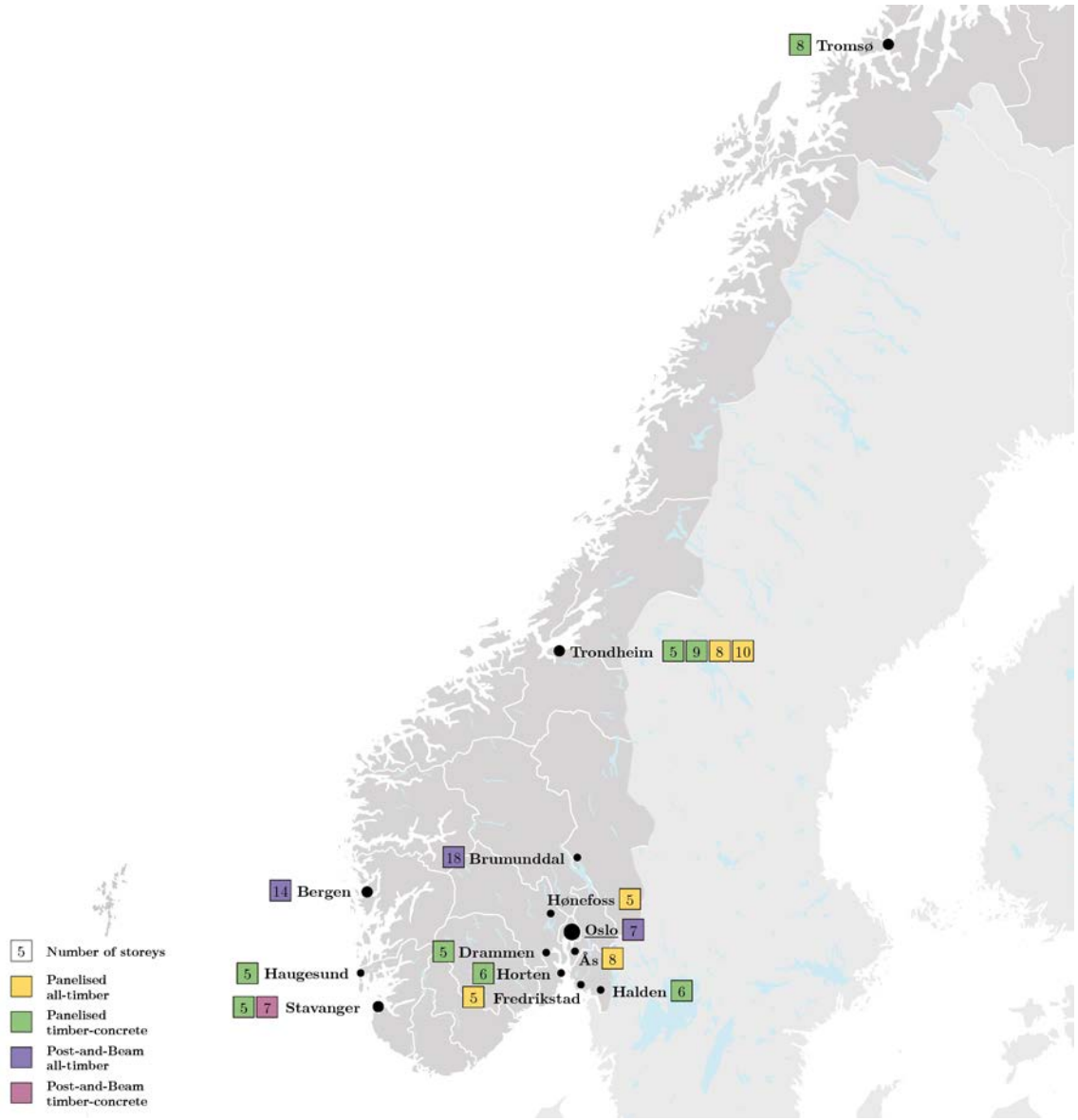

Figure 5.25: Location, structure and number of storeys of the case-studies in Norway

Seventeen Norwegian case-studies were selected. The projects were built between 2005 and 2019, and eight case-studies were completed in the last three years. The actual built buildings are nearly double the initial case-study number. For Projects such as *Palisaden* (two buildings), *Studentboliger Remmen* (four buildings), *Moholt 50/50* (five buildings), *Ringerike Campus* (two buildings), *Dramsvegen* (four buildings), and *Kringsjå studentby* (two buildings), the actual number of buildings rises to thirty. The majority of the case-studies are mid-rise buildings: ten of which are between five to seven-storeys high, whereas seven case-studies range between eight and eighteen storeys. The number of buildings explains why Norway has one of the highest amount of built square meters (approximately 165,200 m^2). As Figure 5.25 shows, the majority of the projects were completed in the south of the country and in the centrally located Trondheim, four projects were completed. Tromsø is the northernmost city in the survey to have completed an MTB.

The vast majority of the case-studies are based on the panelised concept, which can further be subdivided into two groups. *Palisaden* (Nikolaisen, 2013), *Bjølstad Studentboliger* (Bas Arkitekter, n.d.*a*), *Ringerike Campus* (Code Arkitekter, n.d.*c*) (Tunmo, 2016), *Kringsjå studentby* (Joelson, 2018) (Norske arkitekters landsforbund NAL, n.d.), *Maskinparken TRE* (Eliassen et al., 2019*a*) are all-timber projects. *Svartlamoen Housing* (Architecture Norway, 2005) (Triendl, 2005), *Sørhaug-gate* (Helen&Hard, n.d.), *Studentboliger Remmen* (Bas Arkitekter, n.d.*b*), *Moholt 50/50* (Architect Magazine, n.d.), *Dramsvegen* (Woodcon, n.d.), *Øvre Sund* (Tunmo, 2017) (Code Arkitekter, n.d.*a*), and *Fagerlund studenthybler* (Code Arkitekter, n.d.*b*) are timber-concrete projects, with a concrete podium. *Egnes Park* has a concrete core, and no podium (Mayo, 2015). All these projects are similar in the method in which they were built. The majority of them are designed for student housing, so regular shear walls are positioned near one another to form a rigid structure.

The remaining four projects *Valle Wood*, *Treet*, *Mjøstårnet*, and *Bjergsted Financial Park* have structures that fall into the post-and-beam category. *Valle Wood* has a post-and-beam structure with hybrid CLT-concrete floor slabs (Lund+Slaato Arkitekter, n.d.). *Treet*, and *Mjøstårnet* belong to a bracing variation of the all-timber category, having their cores play only a secondary structural role (Green and Taggart, 2017) (Abrahamsen, 2018). The main load bearing system of *Mjøstårnet* consists of *"large scale glulam trusses along the facade as well as internal columns and beams"* (Abrahamsen, 2017). These trusses give to the building the necessary stiffness. *Treet* has a similar system but is 30 meters shorter, and it has 3D modules inserted in the post-and-beam structure (Green and Taggart, 2017). Additionally, Mjøstårnet has prefabricated facade elements which include insulation and external cladding. In both case-studies, the structure is connected to the foundation by use of slotted-in steel plates commonly used in bridges (Abrahamsen, 2017). Both projects include a few floors made of concrete. Located on the upper storeys of the buildings, these floors give weight to the structures and aid their structural behaviour.

Figure 5.26: *Mjøstårnet* under construction and connection to the foundations

Source: Moelven

Bjergsted Financial Park has a post-and-beam timber-concrete structure with its cores made of concrete (Rando, 2019). The majority of the columns and beams of *Treet* and *Mjøstårnet* are made of glulam. *Bjergsted Financial Park* has a more mixed and combined frame instead. It has concrete cores on which a mixed glulam and LVL frame supports the CLT floor slabs (Kropf, 2019). LVL columns and beams are used in the first two floors, while in the upper floors, LVL-glulam

beams are used (LVL is used on the inside part of the beams, glulam on the outside) (Rando, 2019) (see Figure 5.27 on the right). Additionally, these columns are connected with dry timber connections which are similar to the ones used in the Swiss case-studies *Tamedia Office* and *Omega Headquarters*.

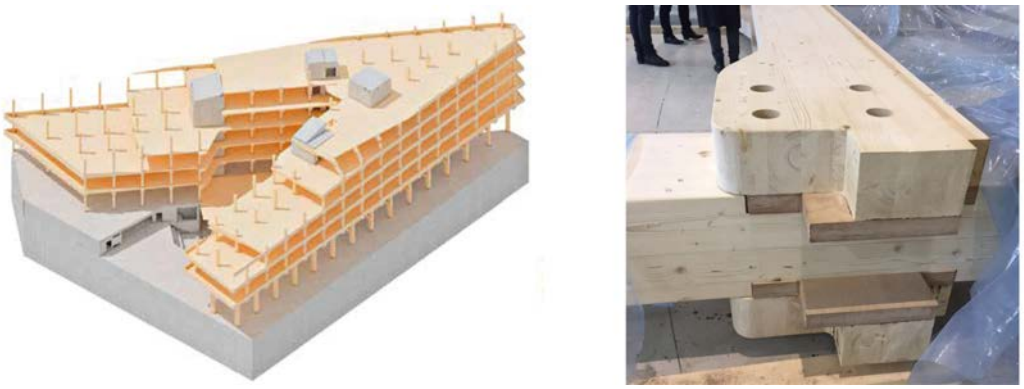

Figure 5.27: *Bjergsted Financial Park*'s structure and example of its formed by LVL and glulam
Source: Helen&Hard / SAAHA

Egnes Park and *Bjergsted Financial Park* are the only two case-studies with concrete cores, whereas all the other case-studies utilised CLT. In some cases, such as *Treet* and Mjøstårnet, the cores do not have a structural role, but they are still made of CLT panels. *Egnes Park* has box timber floor slabs elements, *Valle Wood* has hybrid CLT-concrete slabs, both *Treet* and *Mjøstårnet* have LVL box elements, and all the other projects use CLT as floor slabs.

The majority of these 17 case-studies have the timber structure starting directly at the ground floor level, whereas seven case-studies have a podium made of concrete. Both *Treet* and *Mjøstårnet* have LVL-based box elements, and include a few concrete floors too. These concrete slabs are considered secondary to the overall structure which is considered all-timber in any case, as also done by the CTBUH council (CTBUH, 2019).

The most frequent program in Norway is student housing, with ten case-studies completed. Norway is the country with the highest number of student housing building projects. There are several reasons as to why that is the case, and they will be explained in the next chapter. Four residential buildings (of which the first completed is a social housing project) were also completed. Two projects are office buildings. The tallest case-study, *Mjøstårnet*, has a mixed-use program including flats, offices, hotel and restaurant spaces.

Wood is used in the majority of these case-studies as the main facade material. Some buildings (five case-studies) have a combination of a metallic and wooden facade. *Treet* and *Bjergsted Financial Park* are the two case-studies which do not use wood as main cladding material. They have a metallic and glass facade instead. Timber is always visible on the inside of the buildings except for *Maskinparken TRE*. Most of the projects have all (or some) the structural elements exposed. The majority of the buildings have regular plans and volumes, while only *Bjergsted Financial Park* has more complex geometries.

Table 5.7: List of the Norwegian case-studies and their main design data points

Project (name)	(image)	Storeys (number)	Timber Storeys (number)	Strucutral system (logo)	(category)	Core (material)	Floor Slabs (material)	Total Built Surface (m2)	Program (type)	Facade cladding (material)	Structural timber exposure (category)
Svartlamoen Housing		5	4		Platform timber-concrete (podium)	CLT	CLT	1080	Residential - Social Housing	Wood	All the surfaces
Egnes Park		5	5		Platform timber-concrete (core)	Concrete	LVL box elements	13000	Residential	Wood	All the surfaces
Palisaden		8	8		Platform all-timber	CLT	CLT	4000	Student Housing	Wood/ Metal	Walls
Treet		14	14		Post-and-beam all-timber (external bracing)	CLT	LVL box elements	5830	Residential	Metal	Columns and beams
Sørhauggate		5	4		Platform timber-concrete (podium)	CLT	CLT	1960	Student Housing	Wood	Walls
Studentboliger Remmen		6	5		Platform timber-concrete (podium)	CLT	CLT	9552	Student Housing	Wood/ Metal	Walls
Bjølstad Studentboliger		5	5		Platform all-timber	CLT	CLT	5656	Student Housing	Wood/ Metal	All the surfaces
Moholt 50/50		9	8		Platform timber-concrete (podium)	CLT	CLT	21800	Student Housing	Wood	All the surfaces
Ringerike Campus		5	5		Platform all-timber	CLT	CLT	7500	Student Housing	Wood	Walls
Dramsvegen		8	7		Platform timber-concrete (podium)	CLT	CLT	25000	Student Housing	Wood/Metal	Walls
Øvre Sund		5	4		Platform timber-concrete (podium)	CLT	CLT	5500	Student Housing	Wood/ Metal	All the surfaces
Fagerlund studenthybler		6	4		Platform timber-concrete (podium)	CLT	CLT	9000	Student Housing	Wood	Walls
Kringsjå studentby		10	10		Platform all-timber	CLT	CLT	13106	Student Housing	Wood	Walls
Maskinparken TRE		8	8		Platform all-timber	CLT	CLT	4135	Residential	Wood	None
Bjergsted Financial Park		7	7		Post and beam timber-concrete (core)	Concrete	CLT	13400	Office	Curtain wall	All the surfaces
Mjøstårnet		18	18		Post-and-beam all-timber (external bracing)	CLT	LVL box elements	11300	Mixed Use (residential-other)	Wood	Columns and beams
Valle Wood		7	7		Post-and-beam all-timber	CLT	CLT-concrete	6700	Office	Wood	All the surfaces

5.3.8 Spain

see Appendix pages 412-416

Figure 5.28: Location, structure and number of storeys of the case-studies in Spain

Five case-studies have been selected in Spain. *Contralaminada* was completed in 2014 and the remaining four case-studies were all completed in the last three years of the survey (2017-2019). All the projects are mid-rise buildings, with their storey-height between five and seven. They are formed by single buildings which have different sizes. *15 Buenavista* is one of the smallest case-studies, with around 400 m^2 and *Hondarribia Visesa VPO* is the largest case-study in Spain, with around 9,000 mm^2. 14,500 m^2 is the total amount of square meters built of the Spanish case-studies. Figure 5.28 shows that the majority of the projects were realised in the North-East part of the country, and two projects were completed in the capital Madrid.

All the buildings have a panelised structure. *Contralaminada* has an all-timber structure (Altermateria, n.d.), whereas the remaining four projects have a concrete podium at ground floor with an all-timber structure at the top (Baumad, n.d.) (Tectonica, 2019) (Sapiña, 2019) (Impact-0, n.d.). Additionally, all the projects have a core made of CLT, as all the other main structural elements (walls, shear walls and floor slabs). In some cases, additional glulam columns and beams were used.

All the built case-studies are residential buildings. Both *Contralaminada* and *Hondarribia Visesa VPO* are social housing projects, and *La Borda*, is a co-housing project (Sapiña, 2019). The facade choice is heterogeneous. Wood, ceramic, plaster and metal are the materials chosen for the external cladding of the projects. Structural timber surfaces are left exposed on the ceiling of four case-studies, meanwhile only the facade walls are left visible in the other project *15 Buenavista*. A particular observation which can be made for the Spanish projects is that the majority of them are placed in an urban environment. *Contralaminada*, *ARV8*, *La Borda*, and *15 Buenavista* are all directly inserted between existing buildings in an urban centre or periphery. For this reason, from a composition point of view, all the buildings are regular volumes with squared plans.

Table 5.8: List of the Spanish case-studies and their main design data points

Project *(name)*	*(image)*	**Storeys** *(number)*	**Timber Storeys** *(number)*	**Strucutral system** *(logo)*	*(category)*	**Core** *(material)*	**Floor Slabs** *(material)*	**Total Built Surface** *(m2)*	**Program** *(type)*	**Facade cladding** *(material)*	**Structural timber exposure** *(category)*
Contralaminada		5	5		Panelised all-timber	CLT	CLT	940	Residential - Social Housing	Plaster	Ceiling
Hondarribia Visesa VPO		5	4		Panelised timber-concrete (podium)	CLT	CLT	9000	Residential - Social Housing	Other	Ceiling
ARV8		6	5		Panelised timber-concrete (podium)	CLT	CLT	1200	Residential	Metal	Ceiling
La Borda		7	6		Panelised timber-concrete (podium)	CLT	CLT	3000	Residential - Co-housing	Wood	Ceiling
15 Buenavista		5	4		Panelised timber-concrete (podium)	CLT	CLT	409	Residential	Wood	Walls

5.3.9 Sweden

see Appendix pages 419-433

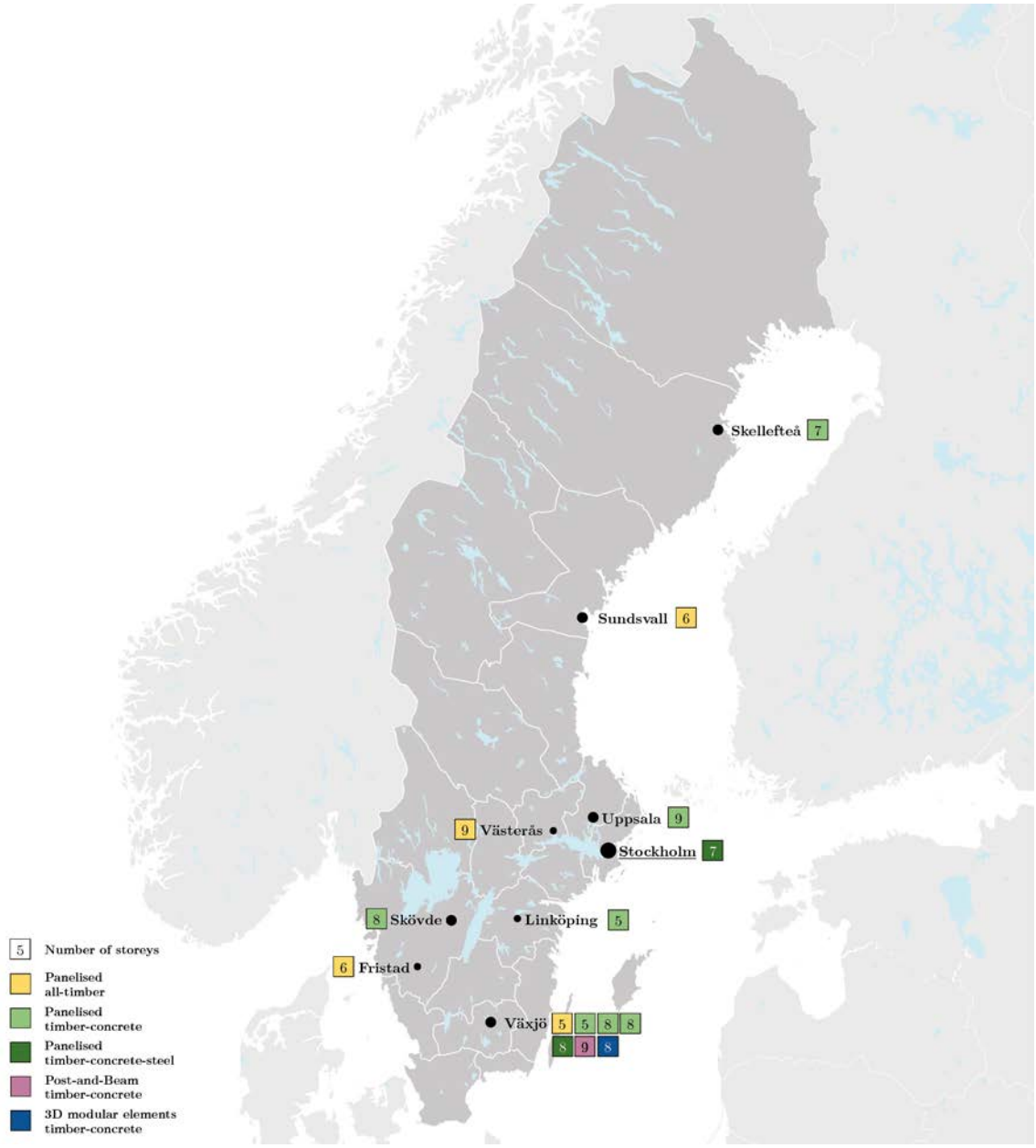

Figure 5.29: Location, structure and number of storeys of the case-studies in Sweden

Fifteen Swedish case-studies were selected, all completed between 2005 and 2019. Seven buildings were completed in the last two years. The majority of these projects consist of a range of between two and four buildings, taking the true number of buildings built to twenty-nine. A slight majority of the projects are high-rise projects, while seven are mid-rise projects. The total amount of square meters built is around 122,000 m^2, and *Trummens Strand* is the largest development, comprising 22,200 m^2 (Fojab, n.d.). Many projects were completed in the city of Växjö. The other Swedish projects are spread all over the country, as Figure 5.29 shows.

The majority of the cases have a panelised system. *Sundsvall I* (Falk, 2005), *Åsbovägen* (Landel,

2018), *Ekologen* (Thorsell, 2018), and *Kajstaden* (ArchDaily, n.d.*b*) are all-timber structures with cores, shear walls, and floors made of CLT. In the case of *Sundsvall I*, the floor slabs were made of CLT-glulam floors (Falk, 2005). *Strandsnäckan* is the only project with only a concrete core and no podium (Arkitektbolaget, n.d.), *Portvakten* (Landel, 2018), *Älvsbacka Strand* (Bengtsson, 2009), *Valla Berså* (Lindsténs, n.d.), *Botanikern* (Axelsson, 2020), and *Trummens Strand* (Fojab, n.d.) all have a concrete podium and CLT cores. *Åsbovägen* (Landel, 2018) has only a concrete podium, and *Frostaliden* rises on the top of a concrete podium and has a concrete core as well.

Strandparken and *Limnologen* both have a panelised timber-concrete-steel structure. Their CLT core and shear wall structures have concrete podiums. Additionally, steel rods run the entire vertical height of the buildings, anchoring the timber structure to the podium, and resisting the uplift forces due to the wind (Landel, 2018) (Green and Taggart, 2017).

The last two case-studies have different structural systems than the panelised system. *Vallen* is the only Swedish case-study which has a post-and-beam timber-concrete structure (Johansson and Schauerte, 2015). The glulam frame is connected to concrete cores and supports LVL box-elements floor slabs. The timber structure sits on the top of a concrete podium (Landel, 2018). *Docenten* has a 3D modular timber-concrete element structure (Thorsell, 2018). The 3D modules are made of timber-frame panels (walls and floors) and are stacked on the top of a concrete podium. They are also connected to the several concrete cores of the building.

Four projects have concrete cores, whereas the rest are designed with CLT. The majority of the Swedish projects have CLT floors, and the first three case-studies had a combination of CLT and glulam floor slabs. *Vallen* has LVL floor slabs, and *Docenten* box timber floor slabs elements. The majority of the case-studies have a podium at the ground floor level made of concrete.

All the Swedish projects are residential buildings, except *Docenten*, which is a student housing. The majority of the cases have simple volumes with pitched roofs. The circular shape of *Valla Berså* is unique in the overall survey. Nearly all of the projects have a wooden cladding, which is made of different types (shingles or boards). Two case studies were found with alternative cladding materials: *Portvakten*, which has a cement-based cladding, and *Docenten* which has a metallic cladding. The majority of the indoor structural timber surfaces are all encapsulated with gypsum boards. Only the three case-studies *Åsbovägen*, *Frostaliden*, and *Trummens Strand* left some surfaces such as walls or ceilings exposed.

Table 5.9: List of the Swedish case-studies and their main design data points

Project (name)	(image)	Storeys (number)	Timber Storeys (number)	Strucutral system (logo)	(category)	Core (material)	Floor Slabs (material)	Total Built Surface (m2)	Program (type)	Facade cladding (material)	Structural timber exposure (category)
Sundsvall I		6	6		Panelised all-timber	CLT	CLT-glulam	5040	Residential	Wood	None
Limnologen		8	7		Panelised timber-concrete-steel (podium-steel rods)	CLT	CLT-glulam	10700	Residential	Wood	None
Portvakten		8	7		Panelised timber-concrete (podium)	CLT	CLT-glulam	5444	Residential	Cement based	None
Älvsbacka Strand		7	6		Panelised timber-concrete (podium)	CLT	CLT	8820	Residential	Wood	None
Strandparken		7	6		Panelised timber-concrete-steel (podium-steel rods)	CLT	CLT	8120	Residential	Wood	None
Åsbovägen		6	6		Panelised all-timber	CLT	CLT	5960	Residential	Wood	Walls
Vallen		9	7		Post-and-Beam timber-concrete (podium-core)	Concrete	LVL	8016	Residential	Wood/Metal	None
Valla Berså		5	4		Panelised timber-concrete (podium)	CLT	CLT	3480	Residential	Wood	None
Docenten		8	6		3D Modular timber-concrete (podium-core)	Concrete	Box elements	9864	Student Housing	Metal	n/a
Ekologen		5	5		Panelised all-timber	CLT	CLT	5332	Residential	Wood	None
Frostaliden		8	6		Panelised timber-concrete (podium-core)	Concrete	CLT	4900	Residential	Wood	Walls
Botanikern		9	8		Panelised timber-concrete (podium)	CLT	CLT	13400	Residential	Wood	None
Kajstaden		9	9		Panelised all-timber	CLT	CLT	7500	Residential	Wood	None
Strandsnäckan		5	5		Panelised timber-concrete (core)	Concrete	CLT	8016	Residential	Wood	None
Trummens Strand		8	6		Panelised timber-concrete (podium)	CLT	CLT	22200	Residential	Wood	Ceiling

5.3.10 Switzerland

see Appendix pages 435-453

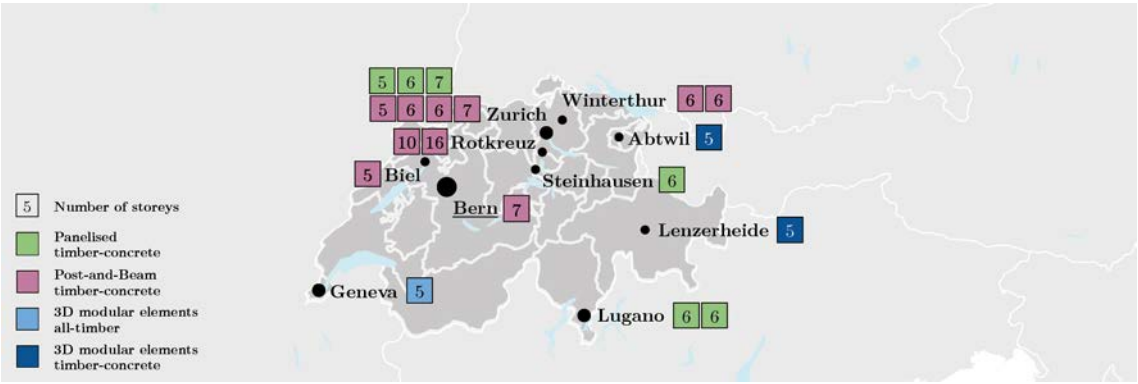

Figure 5.30: Location, structure and number of storeys of the case-studies in Switzerland

Nineteen case-studies have been found in Switzerland, and they were built between 2006 and 2019. Nearly a third of them were built in the last three years. Several projects like *Mühlebachstrasse*, *Giesserei*, *Zollfreilager Housing*,*Asylunterkunft Rigot*, and *Omega Headquarters* all include two or three buildings. These additional buildings bring the Swiss case-study total to twenty-five. The majority of the case-studies are mid-rise, with *Suurstoffi S22* and *Arbo* as exceptions. There are several buildings that are some of the largest developments in the survey. They are *Giesserei*, around 29,300 m^2 (Lignum, 2013), and *sue&til* which has around 53,000 m^2 (Lignum, 2019*a*). The total amount of built square meters of the Swiss buildings is around 226,800 m^2, the highest number for a country in this survey. A considerable amount of case-studies were completed in Zurich (seven case-studies). As Figure 5.30, the other case-studies are located all over Switzerland with three cities having two completed case-studies.

Besides *Asylunterkunft Rigot* (Lignum, 2019*b*), all the other projects are hybrid combinations between timber and concrete. Eleven projects have a post-and-beam timber-concrete structure. In *Wohnhaus Habsburgstrasse* (Lignum, 2012), *Mühlebachstrasse* (Lignum, 2012) (Mayo, 2015), *Tamedia Office* (Green and Taggart, 2017), and *Arbo* (Lignum, 2020) the glulam frame (or mixed glulam and LVL frame in the case of *Arbo*) is connected to concrete cores, but it begins directly at the ground floor level. The remaining seven case-studies have instead both a podium and a concrete (Lignum, 2013) (Kaufmann et al., 2018) (Lignum, 2014*b*) (Lignum, 2015*a*) (Lipsky and Gaujard, 2006) (Lignum, 2019*a*). Between these projects, it is worth giving particular attention to *Tamedia Office* and *Omega Headquarters*. Both the projects have a similar structural system. The columns of their structure are connected to the beams via dry timber connections, which are left visible (Jussel, 2012) (Jussel, 2019). These type of connections are also used in the Norwegian case-study *Bjergsted Financial Park*, and they represent a singularity in the timber construction scenario (Rando, 2019). *Omega headquarters* is part of the Omega building development which includes three buildings built for the Omega Watch company. One timber gridshell building is three storeys tall and was not considered in this survey. The other buildings are rectilinear glazed volumes: a five-story Omega production facility and a museum which is also topped with an

elliptical conference hall. The structure of these two buildings is similar but not identical. The production facility has a central and wide concrete core which is flanked by two glulam-frame wings. This framing supports floor slabs that are a composite of timber and concrete (Gonchar, n.d.). This building has a concrete ground floor podium on one side of the ground floor. The other museum building is also formed by a glulam frame system, and it also has a concrete floor podium. The difference in this case is the presence of a CLT core and external steel cores, whereas the frame is continuous along the entire length of the building.

Figure 5.31: Connection details of *Tamedia Office* and *Omega Headquarters*

Source: Shigeru Ban Architects and Didier Boy de la Tour

Also *Suurstoffi S22* and *Arbo* have evident similarities. *Suurstoffi S22* has two concrete cores on which a glulam frame (with some beams made of LVL) is connected (Suter, 2017) (Lignum, 2020). Steels bars are sometimes used as beams and the ground floor of the building is made of concrete. The floor system is composed of glulam and LVL-concrete pre-assembled floors which are predisposed to accommodate the technical installations (Lignum, 2020). One year later *Arbo* was completed. It also has a post and-beam timber-concrete structure. The underground and the core are made of concrete, but the timber structure begins at the ground floor level (Wehrle, 2019). A mainly LVL-concrete floor slab system is connected to the core and supported by LVL and glulam columns (Lignum, 2020).

Figure 5.32: LVL columns and floor slabs used in *Arbo*

Source: Markus Golinski and Erne AG

Five case-studies have a panelised timber-concrete structure. *Holzhausen* (Affentranger, 2009), *Residenza Sirio* (Lignum, 2015*b*), and *Zollfreilager Housing* (Kaufmann et al., 2018) have the core

made of concrete, *Casa Montarina* has just the podium (Felder, 2009), and *Badenerstrasse* both podium and core (Kaufmann et al., 2018). Additionally, *Badenerstrasse* was designed with the "top wall" system, a solid wood system which was used for the construction of the load-bearing walls (Heinz, 2011) (Kaufmann et al., 2018). The system is formed by floor-to ceiling planks connected to the floors with hardwood dowels. The advantage of this system is the ease of mounting the planks, being made of a size (100x195 mm) easily handled by a two-person team (Heinz, 2011) (see Figure 5.33).

Figure 5.33: Top wall system developed by Blumer Lehmann

Source: Heinz (2011)

The two hotel projects *Hotel Saentispark* and *Hotel Revier* have a similar hybrid 3D modular structure. The pre-assembled modules were stacked on the top of a concrete podium and connected to concrete cores (Lignum, 2019*b*). Also the asylum seekers residence *Asylunterkunft Rigot* was designed with a 3D modular structure, all the structural elements are made of timber, including the foundations (Lignum, 2019*b*).

Except for *Casa Montarina* (no proper core) and *Asylunterkunft Rigot* (3D core modules), all the other projects have concrete cores. The majority of the cases also have the ground floor made of reinforced concrete. Eight projects have their timber structure starting at the ground floor level, and *Asylunterkunft Rigot* is the only case-study with a timber foundation. Floor slab materials are varied. The most commonly used floor slab solution in the Swiss case-studies are the timber-box floors. Only three projects use CLT and four projects have hybrid glulam-concrete floor slabs. The main floor slabs in the *Tamedia office* are supported by the glulam frame of the building. Alternatively, DLT floors were used in three case-studies, and *Mühlebachstrasse* uses hybrid DLT-concrete floors. Most of the cases use glulam for the columns and beams, but the two tallest buildings, *Suurstoffi S22* and *Arbo*, also use LVL.

The programs of the Swiss case-studies is heterogeneous. The majority of the buildings are residential buildings. *Mehr als Wohnen Haus J*, and *Asylunterkunft Rigot* were considered social housing projects. *Mühlebachstrasse* is a mixed use residential-office. Of the other remaining case-studies, four case studies are offices, whereas *Siloah* is the only hospital case-study in the entire world list. Two projects are hotels. The choice of the external cladding is heterogeneous: six case-studies have a wooden cladding, three projects have a metallic cladding, the other three projects have a plaster

cladding. The remaining seven case-studies have glass curtain walls or other materials like eternit or stone. The majority of the case-studies have the structure enveloped. However, the buildings since 2013 are mainly having all the structural elements left visible. All the buildings have regular volumes and plans.

Table 5.10: List of the Swiss case-studies and their main design data points

Project (name)	(image)	Storeys (number)	Timber Storeys (number)	Strucutral system (logo)	(category)	Core (material)	Floor Slabs (material)	Total Built Surface (m2)	Program (type)	Facade cladding (material)	Structural timber exposure (category)
Holzhausen		6	6		Panelised timber-concrete (core)	Concrete	Box elements	2090	Residential	Wood	None
Casa Montarina		6	5		Panelised timber-concrete (podium)	None	Box elements	950	Residential	Other	Ceiling
Badenerstrasse		7	6		Panelised timber-concrete (podium-core)	Concrete	Box elements	13876	Residential	Cement based	None
Wohnhaus Habsburgstrasse		5	5		Post-and-Beam timber-concrete (core)	Concrete	Box elements	2115	Residential	Plaster	None
Residenza Sirio		6	6		Panelised timber-concrete (core)	Concrete	CLT	6069	Residential	Plaster	None
Mühlebachstrasse		6	6		Post-and-Beam timber-concrete (core)	Concrete	DLT-concrete	5520	Mixed Use (residential-office)	Other	None
Giesserei		6	5		Post-and-Beam timber-concrete (podium-core)	Concrete	DLT	29265	Residential - Social Housing	Wood	None
SZU-Betrisbgebaude		6	4		Post-and-Beam timber-concrete (podium-core)	Concrete	Box elements	5127	Residential	Plaster	None
Tamedia Office		7	7		Post-and-Beam timber-concrete (core)	Concrete	Glulam	8905	Office	Curtain wall	All the surfaces
Hotel Saentispark		5	4		3D Modular timber-concrete (podium-core)	Concrete	Glulam-concrete	9725	Hotel	Wood	All the surfaces
Mehr als Wohnen Haus J		5	4		Post-and-Beam timber-concrete (podium-core)	Concrete	DLT	4021	Residential - Social Housing	Other	All the surfaces
Siloah		7	6		Post-and-Beam timber-concrete (podium-core)	Concrete	Box elements	4500	Hospital	Metal	None
Zollfreilager Housing		6	6		Panelised timber-concrete (core)	Concrete	DLT	20050	Residential	Wood	None
Hotel Revier		5	4		3D Modular timber-concrete (podium-core)	Concrete	CLT	4100	Hotel	Wood	All the surfaces
sue&til		6	5		Post-and-Beam timber-concrete (podium-core)	Concrete	Box elements	53000	Residential	Metal	All the surfaces
Suurstoffi S22		10	9		Post-and-Beam timber-concrete (podium-core)	Concrete	Glulam- and LVL-concrete	17900	Office	Metal	All the surfaces
Arbo		16	16		Post-and-Beam timber-concrete (core)	Concrete	LVL-concrete	13513	Office	Curtain wall	All the surfaces
Asylunterkunft Rigot		5	5		3D Modular element all-timber	None	CLT	7070	Residential -Asylumseekers	Wood	All the surfaces
Omega Headquarters		5	4		Post-and-Beam timber-concrete (podium-core)	Concrete	Glulam-concrete	19000	Office	Curtain wall	Columns and beams

5.3.11 United Kingdom

see Appendix pages 456-478

Figure 5.34: Location, structure and number of storeys of the case-studies in the UK

Twenty-three case-studies have been selected in the United Kingdom, which is the highest number selected in a single country. The majority of the projects have one built building, and only *Cobalt Place*, *UEA Blackdale*, and *Press House* have two buildings. The total number of MTBs built in the United Kingdom is therefore twenty-six. These projects were built between 2006 and 2019. Nine of these building were completed in the last three years of the survey. The projects have mixed heights, and nearly a fourth of the buildings are high-rise, whereas the majority are mid-rise. The size of the projects is varied with the buildings ranging from the *Nordic Lofts*' 520 m^2 to the 16,000 m^2 of *Dalston Lane* (Waugh Thistleton Architects, 2018). The total square meters of the UK's built case-studies are around 127,000 understanding that data for two case-studies was incomplete. The vast majority of the projects were realised in London, as Figure 5.34 shows. Five projects were completed in other cities of England, and *Ellerslie Road* was completed in Glasgow (Scotland).

All the case-studies are based on the panelised concept. Eleven of them are all-timber buildings, with shear walls, core and floor slabs made of CLT (Waugh Thistleton Architects, 2018) (Ramboll, n.d.) (Eurban, n.d.*b*) (Mast Architects, n.d.). Ten other projects have the main load bearing structural elements made of CLT, but also have a concrete podium which is usually the ground floor (Waugh Thistleton Architects, 2018) (Fourthdoor, n.d.*d*) (MICA Architects, n.d.) (Eurban, n.d.*c*) (Eurban, n.d.*a*). *Trafalgar Place* has a two-storey podium (Waugh Thistleton Architects, 2018). All these twenty-one projects have a CLT-based structure along with CLT cores and floor slabs. *Dalston Lane* is the tallest case-study in the United Kingdom, and was one of the biggest CLT building by the end of 2019 (Da Col, 2017). In this building a particular solution was applied to avoid the shrinkage of the external CLT walls due to the possible overload of the brick facade.

For this reason, a grout pocket on the external facade as well as on the stability walls was planned in order to avoid a drop of CLT panels (Kemp, 2015) (Harley et al., 2016) (see Figure 5.35).

Figure 5.35: Grout pocket on the external facade in *Dalston Lane*

Source: Harley et al. (2016)

Two buildings structurally differ from the overall homogeneous practice of MTBs in the UK. *Curtain Place* has a hybrid panelised timber-steel system where steel beams and columns are integrated in the CLT panel structure in the first two floors (Waugh Thistleton Architects, 2018). Some steel columns are also designed in the upper floors. *Wenlock Road 17-21* has a hybrid panelised timber-concrete-steel structure (Smith, 2014). A central concrete core is connected to a steel frame and to CLT shear walls and floor slabs (Green and Taggart, 2017). Also the external walls are made of CLT. This hybrid system allows the building to have an irregular volume and to develop throughout a diverse plan in each floor. Shear walls and loading facades, like the floor system, are always made out of CLT. When necessary for the panelised structure, only glulam was used as material for the beams or the columns, except in *Curtain Place*, where steel beams and columns were adopted.

Fifteen of the built case-studies are residential projects and two of them are social housing buildings, with affordable housing flats. Additionally, three case-studies have a mixed use residential program, with *Whitmore Road* and *Curtain Place* mixed with offices and *Pitfield Street* mixed with a cinema. The four projects *UEA Crome Court*, *106 Lewes Road*, *UEA Blackdale*, and *Hands Building* are student housing. *Green House* is an office building. The majority of the buildings have a brick cladding. Alternatively, a metallic cladding was found in six case-studies, followed by two case-studies with wood, and one case-study each for a stone and plaster cladding. Nearly all the buildings do not have any timber surface of the structure visible. Five case-studies have the CLT ceilings exposed. *Hands Building* has the walls of the student rooms visible (MICA Architects, n.d.), and *Nordic Lofts* is the only project which has all the surfaces visible (Waugh Thistleton Architects, 2018). From an architectural mass point of view, mainly all the buildings are composed of regular volumes and floor plans. Two projects have more complex volumes formed by parts of different heights. *Nordic Lofts* has a pitched roof and *Wenlock Road* has an irregular shape, based on a square.

Table 5.11: List of the British case-studies and their main design data points

Project (name)	(image)	Storeys (number)	Timber Storeys (number)	Structural system (logo)	(category)	Core (material)	Floor Slabs (material)	Total Built Surface (m2)	Program (type)	Facade cladding (material)	Structural timber exposure (category)
Fairmule House		5	5		Panelised all-timber	CLT	CLT	2700	Residential	Bricks	Ceiling
Stadthaus		9	8		Panelised timber-concrete (podium)	CLT	CLT	3100	Residential	Metal	None
Birdport House		8	8		Panelised all-timber	CLT	CLT	5500	Residential	Bricks	None
Whitmore Road		6	5		Panelised timber-concrete (podium)	CLT	CLT	1022	Mixed Use (residential-office)	Wood	Ceiling
Kingsgate House		7	5		Panelised timber-concrete (podium)	CLT	CLT	4200	Residential - Social Housing	Other	None
UEA Crome Court		7	7		Panelised all-timber	CLT	CLT	9300	Student Housing	Metal	None
Cobalt Place		6	6		Panelised all-timber	CLT	CLT	10900	Residential	Bricks	Ceiling
Curtain Place		6	6		Panelised timber-steel (podium)	CLT	CLT	2250	Mixed Use (residential-office)	Bricks	Ceiling
Trafalgar Place		5	3		Panelised timber-concrete (podium)	CLT	CLT	1800	Residential	Bricks	None
Wenlock Road 17-21		10	9		Panelised timber-concrete-steel (podium-core-steel frame)	Concrete	CLT	6750	Residential	Wood	None
106 Lewes Road		5	4		Panelised timber-concrete (podium)	CLT	CLT	1650	Student Housing	Bricks	None
Nordic Lofts		5	5		Panelised all-timber	CLT	CLT	520	Residential	Bricks	All the surfaces
UEA Blackdale		6	6		Panelised all-timber	CLT	CLT	16470	Student Housing	Metal	None
Woodberry Down		5	5		Panelised all-timber	CLT	CLT	1575	Residential	Bricks	Ceiling
Bacton Low Rise		5	5		Panelised all-timber	CLT	CLT	7634	Residential	Bricks	None
Dalston Lane		11	10		Panelised timber-concrete (podium)	CLT	CLT	16000	Residential	Bricks	None
Highpoint Terrace		8	8		Panelised all-timber	CLT	CLT	12650	Residential - Social Housing	Metal	None
Hands Building		5	4		Panelised timber-concrete (podium)	CLT	CLT	2700	Student Housing	Other	Walls
Press House		9	8		Panelised timber-concrete (podium)	CLT	CLT	3750	Residential	Bricks	None
Boiler House		7	6		Panelised timber-concrete (podium)	CLT	CLT	4050	Residential	Metal	None
Ellerslie Road		7	7		Panelised all-timber	CLT	CLT	4200	Residential - Social Housing	Bricks	None
Pitfield Street		6	5		Panelised timber-concrete (podium)	CLT	CLT	3750	Mixed Use (residential-other)	Bricks	None
Green House		7	7		Panelised all-timber	CLT	CLT	4645	Office	Plaster	None

5.3.12 Canada

see Appendix pages 480-489

Figure 5.36: Location, structure and number of storeys of the case-studies in Canada

Ten case-studies were selected in Canada. They were built between 2009 and 2018. The case studies have slightly more mid-rise then high-rises projects, with four high-rise realized. *UBC Brock Commons* is the tallest in Canada and was the tallest timber-based building in the world for two years (Green and Taggart, 2017). With the exception of *Arbora*, which is formed by three buildings and is the largest case-study in the survey list at 55,515 m^2 (Lam, 2015), all the other Canadian projects are formed by one building. The total square meters of the Canadian projects adds up to around 140,000 m^2. As Figure 5.36 displays, the case-studies are located in the Western region of British Columbia, and in the Eastern region of Quebec.

Nearly all the projects have a post-and-beam structure. *Wood Innovation Centre* was designed with a post-and-beam all-timber structure with glulam columns and beams, and CLT floor slabs (Green and Taggart, 2017) (Kaufmann et al., 2018). *CSN-Fondaction* (Cecobois, 2011) and *Wilson School of Design* (ArchDaily, n.d.*d*) have a post-and-beam timber-concrete structure with the glulam frame connected to the concrete cores. *Synergia* (Nordic Structures, n.d.), and *Lakeside Resort Expansion* (Structurlam, n.d.) are designed with a glulam frame on the top of a concrete podium.

UBC Brock Commons represents a special variant of the post-and-beam system (Kaufmann et al., 2018). The glulam columns of the building sit on top of a concrete podium and are connected with special connection to CLT floor slabs. These elements are connected to two concrete cores. Similar to the post and slab concrete structure principle, this structure is categorised as post-and-slab timber-concrete (Green and Taggart, 2017).

District 03, and *Origine Condos* have a structural system based on the combination between the panelised system and an internal frame, where a combination of external and internal CLT shear walls are connected to internal columns and beams (Cecobois, 2015)

The columns and beams in *District 03* are left visible inside the building (see Figure 5.37, left). *Origine Condos* has a similar system but its structure sits on top of a concrete podium (Oberholzer, 2016). In both the case-studies, CLT shear walls and facade walls are the majority of the elements and CLT floor slabs are supported in the centre of the buildings by glulam columns and beams (see Figure 5.37, right).

UBC Earth Sciences has a post-and-beam timber-concrete-steel structure, where the concrete cores are connected to a glulam frame which is also stiffened by steel chevron braces (Green and Taggart, 2017).

Figure 5.37: The two variants of the panelised system with an inner glulam frame

Source: Nordic Structures and Stephane Groleau

In the Canadian case-studies, the core is, in most cases, made of CLT. There were four projects in which the core was designed in concrete. Half of the case-studies have a reinforced concrete podium. CLT is mostly used for the floor-slabs. There are three exceptions: glulam-based box-elements were used in *CSN-Fondaction* (Cecobois, 2011), and hybrid Laminated Strand Lumber (LSL) and concrete floors were used in *UBC Earth Sciences* (Green and Taggart, 2017). In some parts of *Wilson School of Design* CLT floors were used, in others Q-Deck-concrete floors were used.

There is no predominant program between the Canadian case-studies, which have heterogeneous types of buildings: three of them are residential buildings, two are offices, two are educational buildings, one is a student housing project, and one is a hotel. Metal cladding and curtain walls are the main types of facade cladding. The only two buildings which are fully encapsulated are the two tallest case-studies *UBC Brock Commons* and *Origine Condos*. *Arbora* has left the glulam frame exposed and *District 03* left the ceilings exposed, and the remaining projects exposed all the structural timber elements. From a composition point of view, all the buildings have regular volumes with mostly square or rectangular plans.

Project (name)	(image)	Storeys (number)	Timber Storeys (number)	Strucutral system (logo)	(category)	Core (material)	Floor Slabs (material)	Total Built Surface (m2)	Program (type)	Facade cladding (material)	Structural timber exposure (category)
CSN-Fondaction		6	6		Post-and-Beam timber-concrete (core)	Concrete	Glulam	5580	Office	Curtain wall	All the surfaces
UBC Earth Sciences		5	5		Post-and-Beam timber-concrete-steel (core-steel bracing)	Concrete	LSL-concrete	15794	Education	Metal	All the surfaces
District 03		6	6		Panelised all-timber and frame	CLT	CLT	5010	Residential	Metal	Ceiling
Wood Innovation Centre		8	8		Post-and-Beam all-timber	CLT	CLT	4820	Education	Wood	All the surfaces
Synergia		6	5		Post-and-Beam timber-concrete (podium-external bracing)	CLT	CLT	6689	Office	Curtain wall	All the surfaces
Arbora		8	7		Post-and-Beam timber-concrete (podium)	CLT	CLT	55515	Residential	Bricks	Columns and beams
Lakeside Resort Expansion		6	5		Post-and-Beam timber-concrete (podium)	CLT	CLT	11850	Hotel	Curtain wall	All the surfaces
Origine Condos		13	12		Panelised timber-concrete (podium and frame)	CLT	CLT	13124	Residential	Metal	None
UBC Brock Commons		18	17		Post and slab timber-concrete (podium-core)	Concrete	CLT	15115	Student Housing	Metal	None
Wilson School of Design		5	5		Post-and-Beam timber-concrete (core)	Concrete	CLT and Q-Deck-concrete	6503	Education	Curtain wall	All the surfaces

Table 5.12: List of the Canadian case-studies and their main design data points

5.3.13 United States of America

see Appendix pages 491-504

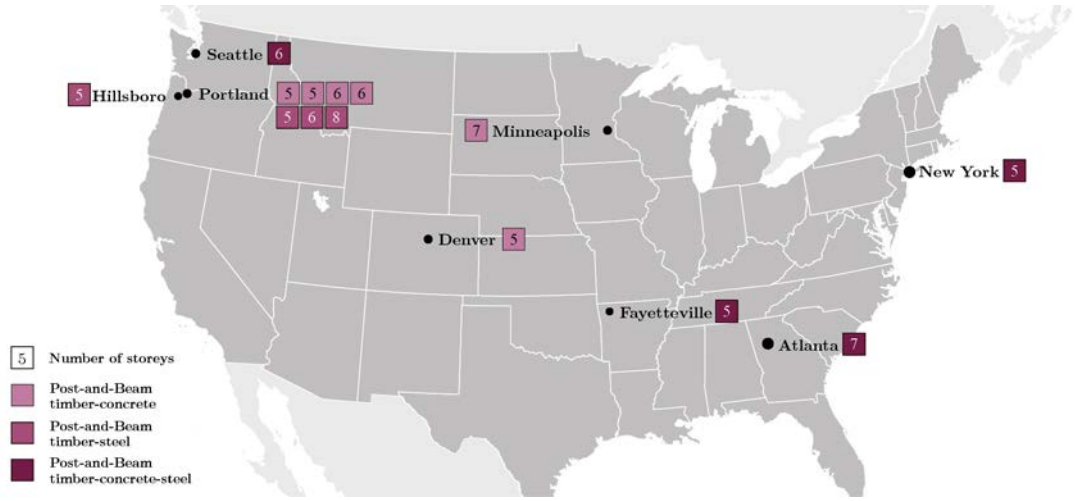

Figure 5.38: Location, structure and number of storeys of the case-studies in the US

Fourteen case-studies have been selected in the USA. They were built between 2013 and 2019, but eight of them were completed in the last two years (2018-2019). Of the selected projects, the vast majority are mid-rise buildings and only *Carbon 12* is over eight-storeys tall. *Adohi Hall* is the only project that contains two buildings, so there are a total of fifteen buildings built in the USA. The sum of the built surface is around 128,300 m^2 with both *Adohi Hall* and *T3 Atlanta* having around 19,000 m^2 (ArchDaily, n.d.*a*) (StructureCraft, n.d.). Half of the case-studies were built in Portland (seven case-studies), and the rest of the projects are spread across several American cities.

All the American case-studies have a post-and-beam structure. The majority of the projects also rely on steel structural elements, which is distinct to American buildings. Four projects have a post-and-beam timber-steel structure. *Clay Creative* has an external frame (Kramer-Gehlen, 2020), *Radiator* (Lipsky and Gaujard, 2013), *Carbon 12* (BuildingCarbon12, 2020), and *First Tech Federal Credit Union* (Structurlam, 2020*a*) have steel cores and internal steel braces which stiffen the glulam frame of their structures. Alternative post-and-beam structures are designed with hybrid combinations between timber and concrete. *38 Davies* is the only case-study that has a post-and-beam all-timber structure on the top of a concrete podium (Think Wood, n.d.*a*). *Framework* (Brake, 2015), *T3* (Green and Taggart, 2017), *Flatiron PDX* (Structurlam, 2020*b*), and *Platte Fifteen* (Think Wood, n.d.*b*) (Think Wood, 2020) all instead have a post-and-beam timber-concrete structure, with concrete podiums and cores connected to a glulam frame.

The architects of *Framework* wanted to directly reference the historical Portland warehouses, but with a new perspective, without the need of the structural external facade (Basalyga, 2020) It resulted in a clear architectural gesture: the massive concrete podium contrasts with the light upper timber structure, which is covered with glass (see Figure 5.39, left). *Flatiron PDX* displays the volumetric possibilities which are still achievable with timber. Even if the building has a two-

storey concrete podium, and concrete cores, (besides some concrete shear walls as well), it has a glulam frame which allows several intersections. These intersections characterise the corner of the plan (see Figure 5.39, right). *Sideyard* has a post-and-beam timber-concrete structure with a concrete core (Think Wood, n.d.*c*).

Figure 5.39: *Framework* and *Flatiron PDX*

Source: Joshua Jay Elliot and Lincoln Barbour

Combinations with timber-concrete-steel are also present. *Bullit Center*'s glulam structure rises on the top of a two-storey concrete podium, but the building has a central steel frame which acts as its core. Chevron steel braces also help to stiffen the structure (Green and Taggart, 2017). In *360 Wythe*, a lateral concrete core is connected to a glulam frame and stiffened together with steel braces (Nonko, 2018). A different combination is represented by *Adohi Hall* (ArchDaily, n.d.*a*). Here, a steel podium (this is the only case-study in the survey where this appears) supports a glulam frame which also has CLT shear walls. Concrete cores complete the LLRS of the building. Finally, *T3 Atlanta* has a concrete podium on which a glulam frame is anchored. The lateral system consists of perimeter and internal steel brace frames (StructureCraft, n.d.).

Half of the case studies have a concrete core, whereas only four of the fifteen projects have a steel core. Three projects do not have a structural core thanks to their frame. Half of the case-studies have a podium made of reinforced concrete, except for *Adohi Hall*, where a steel frame podium was designed. NLT and CLT floor slabs are used in the same amount of case-studies and they both have one hybrid variation with a concrete layer on the top. NLT's floors were found in the majority of the early case-studies, whereas the latest projects mostly have CLT floors. The other floor slabs reported are a special combination of tongue and groove decking, laid diagonal in *Framework* and DLT slabs used in *T3 Atlanta*.

Most of the USA case-studies are office buildings, *38 Davis* and *Flatiron PDX* are both mixed use residential-office buildings, and *Adohi Hall* is student housing. Lastly, *Carbon 12* is the only residential building. From a composition point of view, the choice of the facade material is metal in eight of the case studies, followed by five case-studies with a brick facade and two with a glass curtain wall facade. All the case-studies expose the structural timber elements inside their spaces. Besides the previously described *Flatiron PDX*, the other projects are formed by regular volumes with the majority of them having a regular plan.

Project (name)	(image)	Storeys (number)	Timber Storeys (number)	Strucutral system (logo)	(category)	Core (material)	Floor Slabs (material)	Total Built Surface (m2)	Program (type)	Facade cladding (material)	Structural timber exposure (category)
Bullitt Center		6	4		Post-and-Beam timber-concrete-steel (podium-core-steel bracing)	Steel Frame	NLT	4831	Office	Metal	All the surfaces
Radiator		5	5		Post-and-Beam timber-steel (steel core and bracing)	Steel Frame	NLT	3279	Office	Metal	All the surfaces
Framework		5	4		Post-and-Beam timber-concrete (podium-core)	Concrete	Tongue and groove decking	2323	Office	Curtain wall	All the surfaces
38 Davis		6	5		Post-and-Beam timber-concrete (podium)	None	NLT	12077	Mixed Use (residential-office)	Bricks	All the surfaces
Clay Creative		6	6		Post-and-Beam timber-steel (external frame)	None	NLT-concrete	8361	Office	Bricks	All the surfaces
T3		7	6		Post-and-Beam timber-concrete (podium-core)	Concrete	NLT-concrete	16722	Office	Metal	All the surfaces
360 Wythe		5	5		Post-and-Beam timber-concrete-steel (core-steel bracing)	Concrete	NLT	6039	Office	Bricks	All the surfaces
Carbon 12		8	8		Post-and-Beam timber-steel (steel core and bracing)	Steel Frame	CLT	3902	Residential	Metal	All the surfaces
First Tech Federal Credit Union		5	5		Post-and-Beam timber-steel (steel core and bracing)	Steel Frame	CLT	14493	Office	Metal	All the surfaces
Flatiron PDX		6	4		Post-and-Beam timber-concrete (podium-core)	Concrete	CLT-concrete	2601	Mixed Use (residential-office)	Metal	All the surfaces
Adohi Hall		5	4		Post-and-Beam timber-concrete-steel (steel podium-core)	Concrete	CLT	18769	Student Housing	Metal	All the surfaces
Platte Fifteen		5	4		Post-and-Beam timber-concrete (podium-core)	Concrete	CLT	13974	Office	Bricks	All the surfaces
Sideyard		5	5		Post-and-Beam timber-concrete (core)	Concrete	CLT	1858	Office	Bricks	All the surfaces
T3 Atlanta		7	6		Post-and-Beam timber-concrete-steel (podium-steel bracing)	None	DLT	19045	Office	Curtain wall	All the surfaces

Table 5.13: List of the American case-studies and their main design data points

5.3.14 Australia

see Appendix pages 506-514

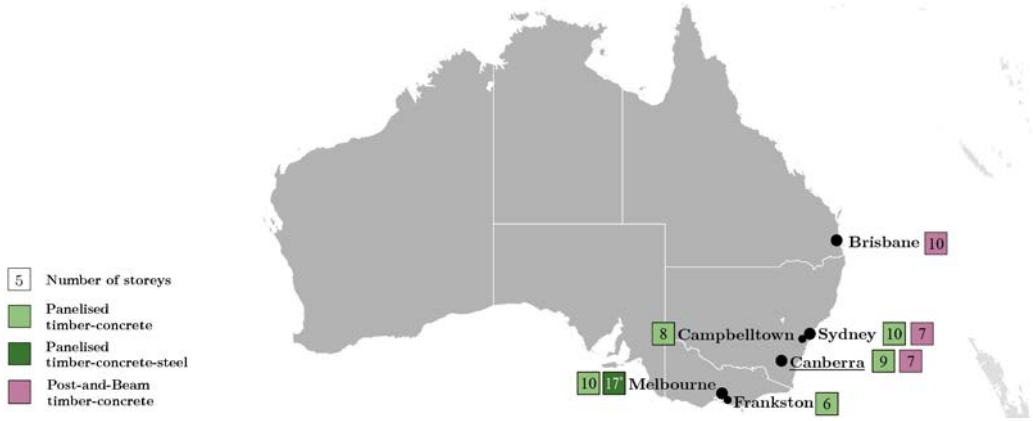

Figure 5.40: Location, structure and number of storeys of the case-studies in Australia

Nine case-studies were selected in Australia. *Forté* was built in 2012, and all the other projects were completed in the last two years of the surveys (2018-2019). There are eleven buildings in total since, *The Gardens Macarthur* encompasses three buildings. Australia has more high-rise buildings, having one eight-storey, one nine-storey, and four ten-storey buildings (including the then additional storeys of *55 Southbank Boulevard*). The data on the precise square meters of the two *Kambri* projects were not available. With a rough calculation, nearly 120,000 m^2 were built in total, with *The Gardens Macarthur* being the biggest Australian development resulting in 22,000 m^2 (MakeitWood, 2020). The Australian projects are all located in the East and South-East part of Australia, and they are distributed between the different cities.

All the buildings have a concrete podium (of varying heights), and they are divided between panelised timber-concrete or post-and-beam timber-concrete structures. When projects are based on the panelised structure, they have the facade walls made of CLT. On the other hand, when the project have a post-and-beam structure, the external walls are formed by glass curtain walls which allow the timber structure to be visible from the outside. *25 King* (Lake et al., 2017), *Daramu House* (Evans, 2018), and *Kambri-CLE* (Titchkovsky, 2018) all have a glulam frame which includes

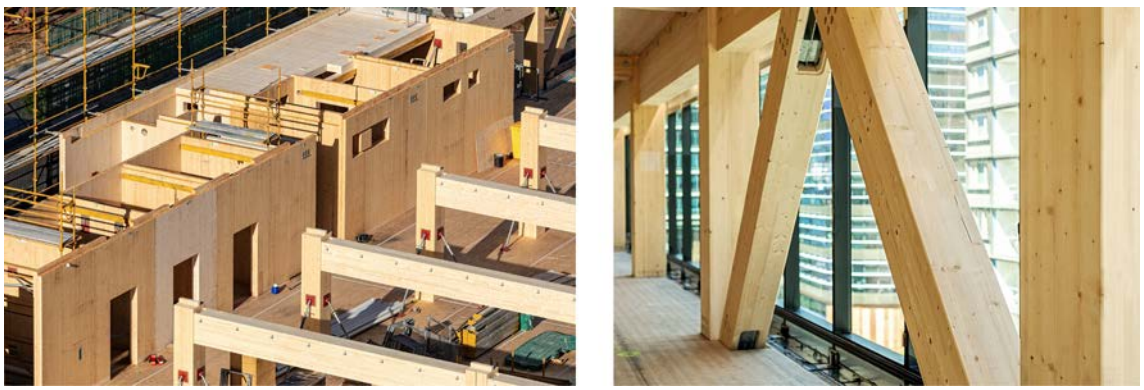

Figure 5.41: *25 King* core and frame, and diagonal beams in *Daramu House*

Source: Lendlease and Aurecon

several diagonal glulam bracing beams (see Figure 5.41). Their structure also has CLT cores and is anchored on a concrete podium.

Forté (Lendlease, 2013), *Aveo Norwest* (CTBUH, 2017), *Garden MacArthur* (MakeitWood, 2020), *Gilles Hall* (Angeli, 2019), and *Kambri-Student accommodation* (Titchkovsky, 2018) are composed of CLT shear walls, core and floor slabs. *55 Southbank Boulevard* rises on the top of an existing six-storey concrete building and after an intermediate floor, the new ten-storey addition begins, with two steel lateral cores. All the projects have a concrete podium, however, none of them have concrete cores. CLT was always the EWP chosen for the core. CLT is also the preferred structural floor material for the floor slabs. Only *Kambri-CLE* is designed with a timber-cassette floor system (Titchkovsky, 2018).

The program is heterogeneous with several significant examples. *Forté* and *Garden MacArthur* are residential buildings, (*25 King* and *Daramu House*) are offices, *Aveo Norwest* is a senior living home, (*Gilles Hall* and *Kambri-Student accommodation*) are student housing projects, and *Kambri-CLE* is an educational building. The indoor exposure of the timber structural elements is different across projects. *Aveo Norwest* and *55 Southbank Boulevard* are fully encapsulated with no timber visible. Other projects show at least a timber element (ceiling or walls) like *Forté*, *Gilles Hall*, and *Kambri-Student Building*. While *25 King*, *Daramu House*, and *Kambri-CLE* have all the structural timber elements exposed. From a composition point of view, the choice of the facade material also varies across projects. The exterior cladding of the case-studies vary from metal, curtain wall, bricks and plaster. All the buildings are architecturally regular volumes with rectangular plans.

Project *(name)*	*(image)*	Storeys *(number)*	Timber Storeys *(number)*	Strucutral system *(logo)*	*(category)*	Core *(material)*	Floor Slabs *(material)*	Total Built Surface *(m2)*	Program *(type)*	Facade cladding *(material)*	Structural timber exposure *(category)*
Forté		10	9		Panelised timber-concrete (podium)	CLT	CLT	2890	Residential	Metal	Walls
25 King		10	9		Post-and-Beam timber-concrete (podium-external bracing)	CLT	CLT	14921	Office	Curtain wall	All the surfaces
Aveo Norwest		10	8		Panelised timber-concrete (podium)	CLT	CLT	18510	Senior living	Other	None
Daramu House		7	6		Post-and-Beam timber-concrete (podium-external bracing)	CLT	CLT	10000	Office	Curtain wall	All the surfaces
The Gardens Macarthur		8	7		Panelised timber-concrete (podium)	CLT	CLT	22000	Residential - Social Housing	Metal	n/a
55 Southbank Boulevard		17	10		Panelised timber-concrete-steel (podium-core)	CLT	CLT	14493	Hotel	Curtain wall	None
Gillies Hall		6	5		Panelised timber-concrete (podium)	CLT	CLT	6500	Student Housing	Metal	Ceiling
Kambri-Student accomodation		9	6		Panelised timber-concrete (podium)	CLT	CLT	22000	Student Housing	Bricks	Walls
Kambri-CLE		7	6		Post-and-Beam timber-concrete (podium-external bracing)	CLT	Cassette floor system	8575	Education	Curtain wall	All the surfaces

Table 5.14: List of the Australian case-studies and their main design data points

5.3.15 Other Countries

see Appendix pages 516-518

Figure 5.42: Location, structure and number of storeys of the case-studies in the other countries

Three case-studies were found in Chile, New Zealand and Taiwan, and they were collected under a single group. The Chilean project *Los Bronces* is actually composed of eight identical buildings and is one of the biggest developments of the survey, with nearly 37,000 m^2 built. All the three case-studies are mid-rise buildings completed between 2012 and 2019. No similarities have been found between the case-studies.

Te Ara Hihiko is the only example of post-and-beam timber-concrete-steel building with a concrete podium and steel rods. The first two floors form the podium of the building and are made of reinforced concrete. The remaining three-storeys are built with concrete cores, an LVL frame with a post-tensioned steel system, which were specially designed to withstand earthquakes (Mayo, 2015). The GLRS is composed of the LVL frame and LVL-concrete floor slabs (Mayo, 2015). All the LVL columns and beams are visible on the inside of *Te Ara Hihiko*.

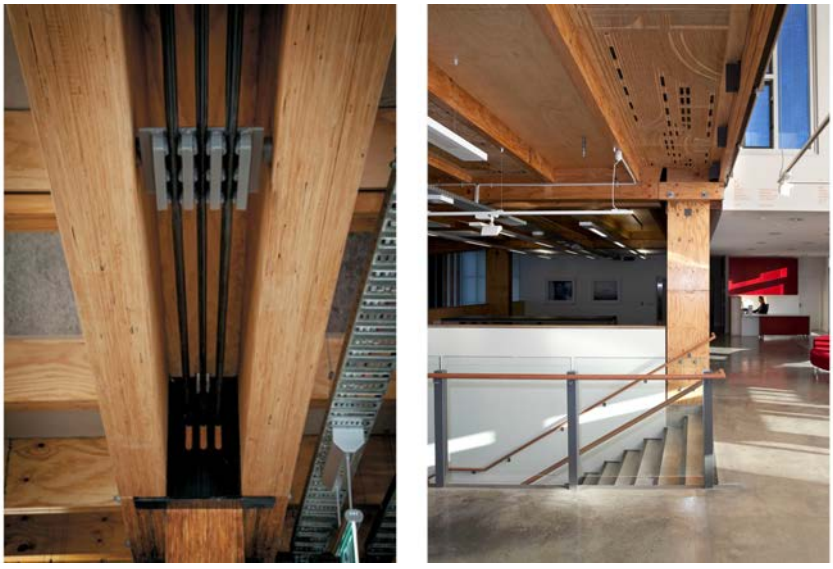

Figure 5.43: Post-tensioned steel system visible in *Te Ara Hihiko*

Source: Jeff Brass and Matt Paterson

A curtain wall with large glass panels covers the building and allows you to see the timber frame from the outside. The architectural mass of *Te Ara Hihiko* is marked by the podium floors and the upper part, evidenced by a different material of the facade.

WoodTek HQ is a five-storey office. Its all-timber panelised structure begins on the top of a reinforced concrete podium (ArchDaily, 2015). CLT is used for all the main structural elements which form the LLRS and GLRS. CLT is also left visible inside the building. The exterior of the building is instead covered with a metallic cladding. The architectural mass *WoodTek HQ* has an irregular volume formed by progressive steps forward of the floors, on the top of the previous one.

Los Bronces was completed in 2019 in Chile. It is composed of eight similar buildings built near a mine and its main function is to house the workers. The structure of the project is made of 3D modular timber elements. These modules are connected to a central glulam frame, and they are placed on the top of a concrete foundation (Montaño et al., 2018). A wooden cladding covers each module which arrived assembled with external and interior finishing. Inside, the glulam frame is visible in the corridor, and no data of the indoor timber exposure of the rooms was found.

Project *(name)*	*(image)*	**Storeys** *(number)*	**Timber Storeys** *(number)*	**Strucutral system** *(logo)*	*(category)*	**Core** *(material)*	**Floor Slabs** *(material)*	**Total Built Surface** *(m2)*	**Program** *(type)*	**Facade cladding** *(material)*	**Structural timber exposure** *(category)*
Te Ara Hihiko		5	3		Post-and-Beam timber-concrete-steel (podium-steel rods)	None	LVL-concrete	3500	Education	Curtain wall	All the surfaces
WoodTek HQ		5	4		Panelised timber-concrete (podium)	CLT	CLT	600	Office	Metal	All the surfaces
Los Bronces		6	6		3D Modular element all-timber	None	Box element	36980	Hotel	Wood	All the surfaces

Table 5.15: List of the other countries case-studies and their main design data points

5.4 How MTBs Were Designed

In the previous section, the case-studies were analysed under several design categories, and were kept divided by country. In this section, the main findings are now compared between each country. The data are presented through comparative schemes and charts, in order to display evident differences (or commonalities) between countries. The goal is to answer the question: how were MTBs designed? National differences were already apparent at the end of Chapter 4, but after the design analysis their differences have become even more evident. As hypothesized at the beginning of this dissertation, this final section proves that there are international trends and differences in the design of MTBs, along with specific variations in the choice of the structural systems, structural characteristics (core, podium, floors), and other design aspects.

To start, the mid-rise and high-rise ratio was compared, along with the number of buildings per project. The comparison of the built square meters provides another level of analysis between the countries and the mid-rise and high-rise relationships. This first analysis makes it clear that no specific country can be considered the best performing country, but instead a set of several forerunners emerge in MTB construction throughout the years surveyed. The structural analysis proves that there are several trends: for example, hybrid buildings are the majority of the case-studies, CLT is the favourite material for floor slabs, and most of the case-studies lie on the top of a concrete podium. Projects with a panelised-based system have a slight majority in the overall case-studies, but there are several countries where they represent a minority of the case-studies (or none). Similar considerations can be made for floor slabs and core materials as well, in which an international trend is recognisable, but there are national nuances which should be noted. From the analysis of other design aspects, it is possible to identify some general commonalities between the buildings, as well as specific national differences. The overall findings are collected at the end of this section. They prove that countries in similar world regions (like Scandinavia or North America), share some similar design solutions, but often differ from one another. This speaks to how much MTBs differ between countries, even in close proximity to one another.

5.4.1 Differences Between Mid-Rise and High-Rise Projects

In this dissertation, mid-rise buildings were considered projects from five- to seven-storeys. High-rise buildings were considered all the projects taller than eight-storeys (eight-storey included). According to this definition, 143 of the 197 selected case-studies are categorised as mid-rise buildings. High-rise projects are nearly one fourth of all of them, with 54 completed buildings (see Figure 5.44). Furthermore, half of the high-rise projects are eight-storey buildings, making the percentage of case-studies taller than eight, just 13,8%. These are general tendency observed from the overall data. These tendencies are not always true for all the countries as Figure 5.45 shows. The distribution of mid-rise and high-rise cases in each country varies, and there are even countries where high-rise projects are more than mid-rise projects. This is the case for Australia and Sweden.

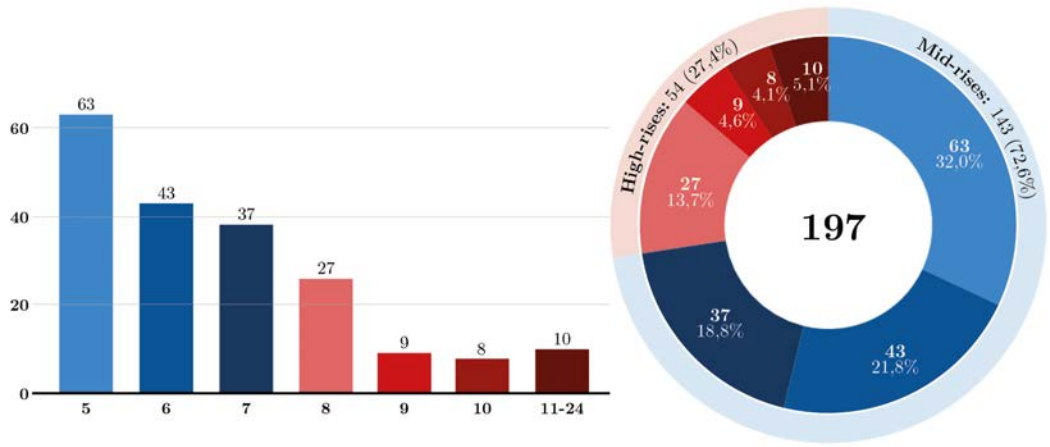

Figure 5.44: Ratio of mid-rise and high-rise projects (counting case-studies/projects)

Other countries have more mixed projects, like France, and Norway. On the other hand, not every country has a built case study higher than a mid-rise. This is the case for countries like Belgium, Chile, New Zealand, Spain, and Taiwan.

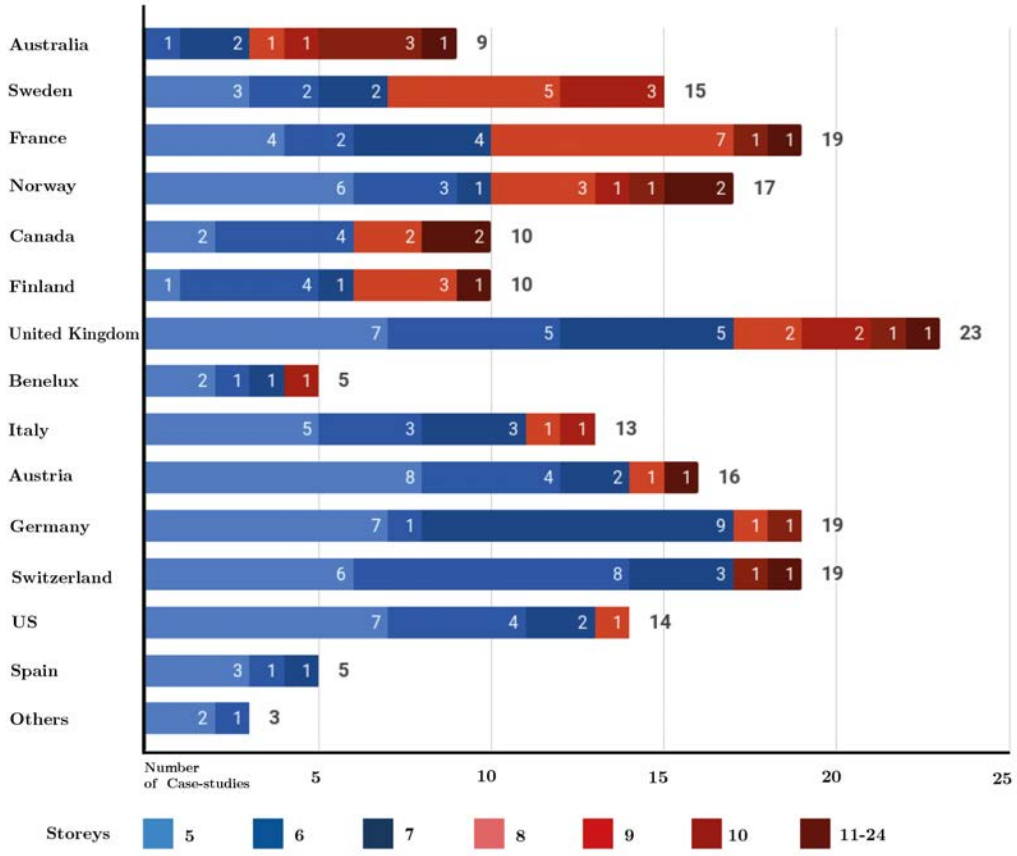

Figure 5.45: Number of mid-rise and high-rise cases-studies divided by country

Through the analysis carried out in the previous section, it emerged that some selected case-studies are, in reality, composed of several buildings. Most of the time both the academic publications and other sources refer to MTBs as unique projects, and most of the time they are. However, 40 of the case-studies consist of more than one building, resulting in a total number of 272 buildings. Figure 5.46 displays the countries arranged by the total of individual buildings of the selected case-studies.

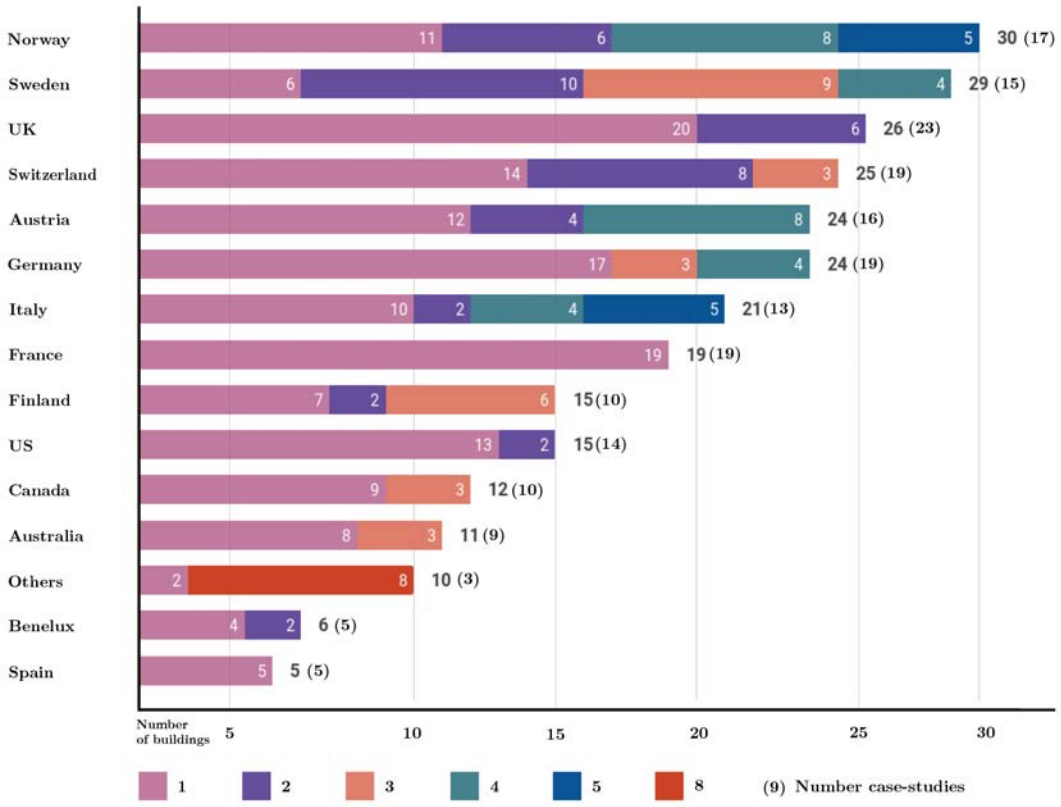

Figure 5.46: Number of individual buildings in each country

It emerged from this data that the Norwegian and the Swedish case-studies are the projects with the highest number of buildings, with the majority of the case-studies being composed of more than a single building. This, makes the two countries reach 30 and 29 buildings. Figure 5.46 also shows that majority of the countries have more than one (or several) case-studies which include more than one building. Only France and Spain do not have any multi-building projects.

In Figure 5.47 the numbers of the mid-rise and high-rise projects are re-arranged following the data derived from Figure 5.46. Even if the numbers grow, the proportion between the storeys remain overall similar to the project-based Figure 5.44.

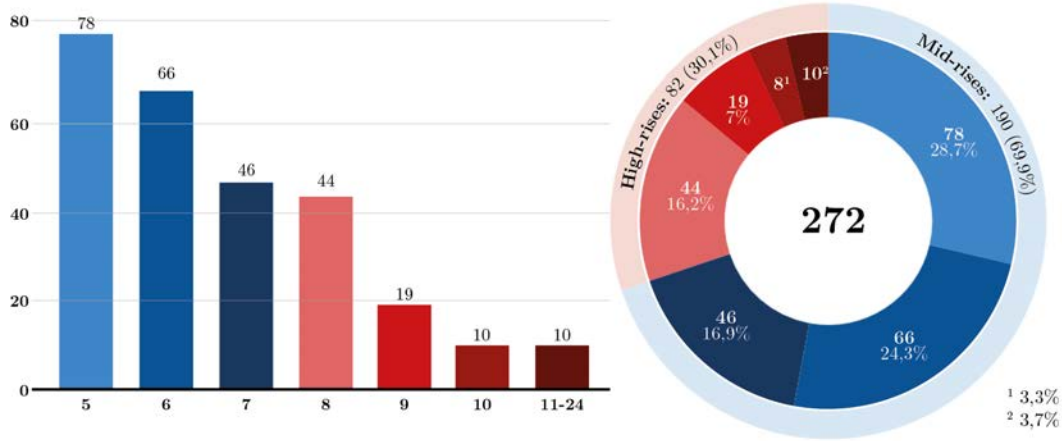

Figure 5.47: Ratio of mid-rise and high-rise projects (counting buildings)

Other considerations can be made based on the analysis of the built square meters per country and their relation to the number of inhabitants. Figure 5.48 organises the amount of built square meters divided according to the total square meters of both mid-rise and high-rise projects in each country. The countries mix themselves considerably if we look at these parameters and the majority of them have more than a total of 100,000 m^2 built.

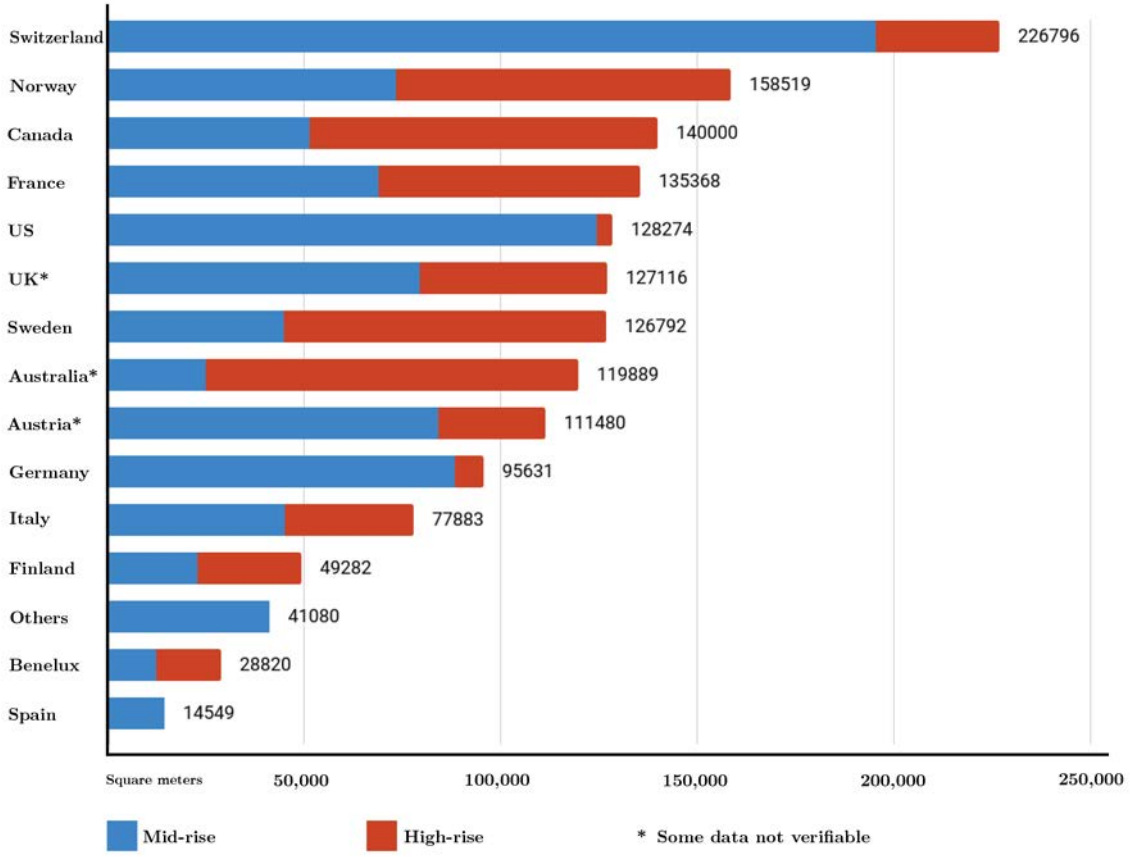

Figure 5.48: Total square meters of the selected case-studies in each country

By this analysis, Switzerland is the country with the highest amount of square meters. As explained in the analysis of the country (see Section 5.3.10), two buildings alone (*Giesserei* and *sue&til*), represent together 83,300 m^2. The majority of the other countries has values which are more homogeneous between each other, with differences which lies in the ratio of square meters of high-rise and mid-rise projects. In this regard, high rise square meters are a much more relevant aspect in many countries. They represent the majority of the built square meters in Norway, Canada, Australia, and Sweden, and are equal to the square meters of the mid-rise case-studies in France, and Finland.

Figure 5.49 gives another interpretation of the data collected and shows the real impact of built square meters in a country. The countries are arranged according to the number of MTBs' square meters every 100,000 inhabitants. Norway, Switzerland, Finland, and Austria are the first four leading countries in this chart. In Figure 5.49 are also displayed the three regions in North America which emerged as the main location of the construction of MTBs: British Columbia and Quebec in Canada, and the Pacific Northwest Region (Washington and Oregon states) in the US.

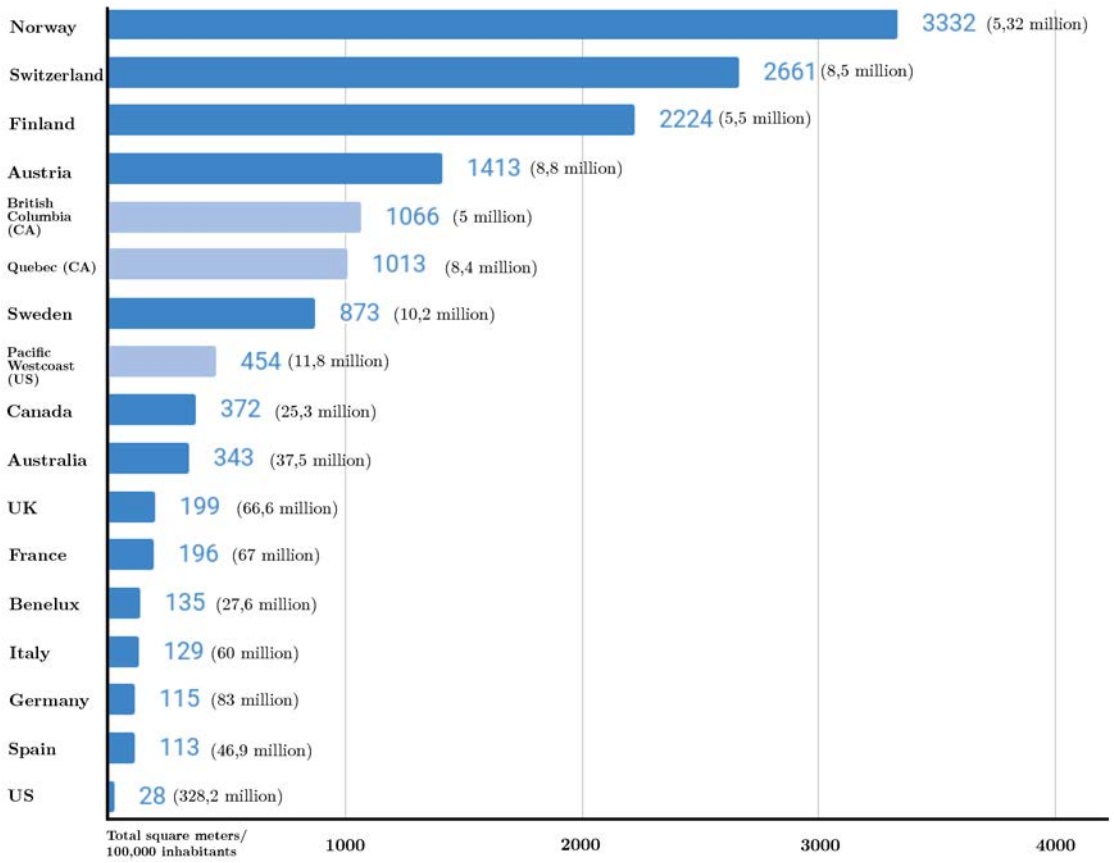

Figure 5.49: Number of inhabitants divided by the total square meters of the selected case-studies in each country

This first part presented an alternative point of view to the analysis carried out in Chapter 4, evidencing the high number of mid-rise buildings, the actual number of buildings in each project and the total number of built square meters per country. While the United Kingdom appeared to be the leading country in Chapter 4, we only needed to change the parameter of analysis to see that the leading countries change depending on the parameter used to measure them. Especially in the analysis of the build square meters, the chart highlights a cluster of countries which built a considerable number of square meters, suggesting that the majority of the analysed countries are in the forefront of the construction of MTBs.

5.4.2 Structural Design of MTBs

Section 5.3 presented the 32 structural categories used in this dissertation. Below, Figure 5.50 displays the overall distribution of the different categories. We can observe that 108 case-studies (55%) are based on the panelised concept. Of these projects, the majority (73 case-studies) have a panelised timber-concrete structure. In Figure 5.50 the structures with a podium are separated from the other combinations (core and podium-core). This shows that the biggest group of projects is the panelised timber-concrete buildings with the concrete podium. A more detailed analysis of the different sub-types will be discussed later (see Figure 5.53). The post-and-beam category

represents the 36% of the case-studies, with 71 projects. The categories with a concrete core or with both a concrete core and podium are more frequent than the others. 3D modules structures represent the 9% of the case-studies. While the majority are hybrid combinations, a third of them have a concrete podium with an all-timber structure on the top of it.

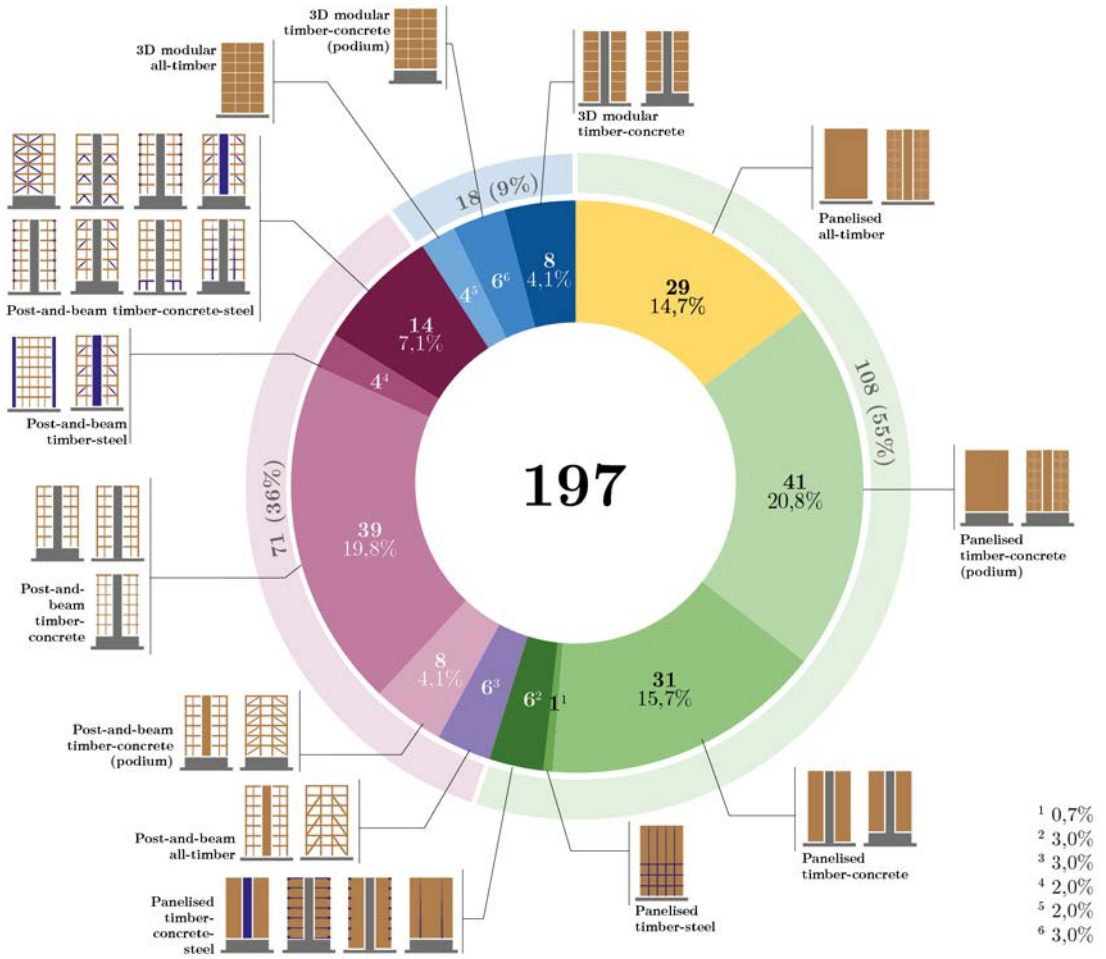

Figure 5.50: The ratio of the different structural systems

As for other aspects such as number of case-studies or mid- and high-rise ratio, there are also national differences according to the structural concepts used in every country (see Figure 5.51). Panelised-based concepts are the majority in eight countries[1]. In Germany, neither panelised nor post-and-beam system prevail. On the other hand, in the USA, France, Switzerland and in Canada, the majority of the buildings are based on the post-and-beam concept. Finland is the only country where 3D modules are the main structural system, meanwhile Benelux and Other countries all have different types of structures. These differences make it difficult to imagine that regions of the world with a similar constructive practice of MTBs exist. This is especially true if we look at the European regions. In Scandinavia, both Sweden and Norway have similar structural systems. There are some nuances represented by the singularity of the post-and-beam all-timber with bracing in Norway, or the panelised timber-concrete-steel in Sweden. Finland, as previously mentioned, has a prevalence of 3D modular buildings. In the Central region of Europe, the differences are

[1]Belgium is considered a separate country in this count.

even more evident. The countries have similar structural systems but with differing numbers. In Austria the majority of the projects are based on the panelised concept, whereas in Switzerland they are mainly based on post-and-beam. Germany stays exactly in the middle with equal number of case-studies for each of these categories. In North America, Canada and the United States have a similar ratio of structures. However, a considerable number of American case-studies have post-and-beam timber-steel combinations, which is a unique practice in comparison with all the other countries. Another relevant finding is the highly heterogeneous distribution of systems in countries like France and Germany, especially in comparison to the case-studies in the UK, Finland and Spain. The reason for these differences is investigated in the next chapter.

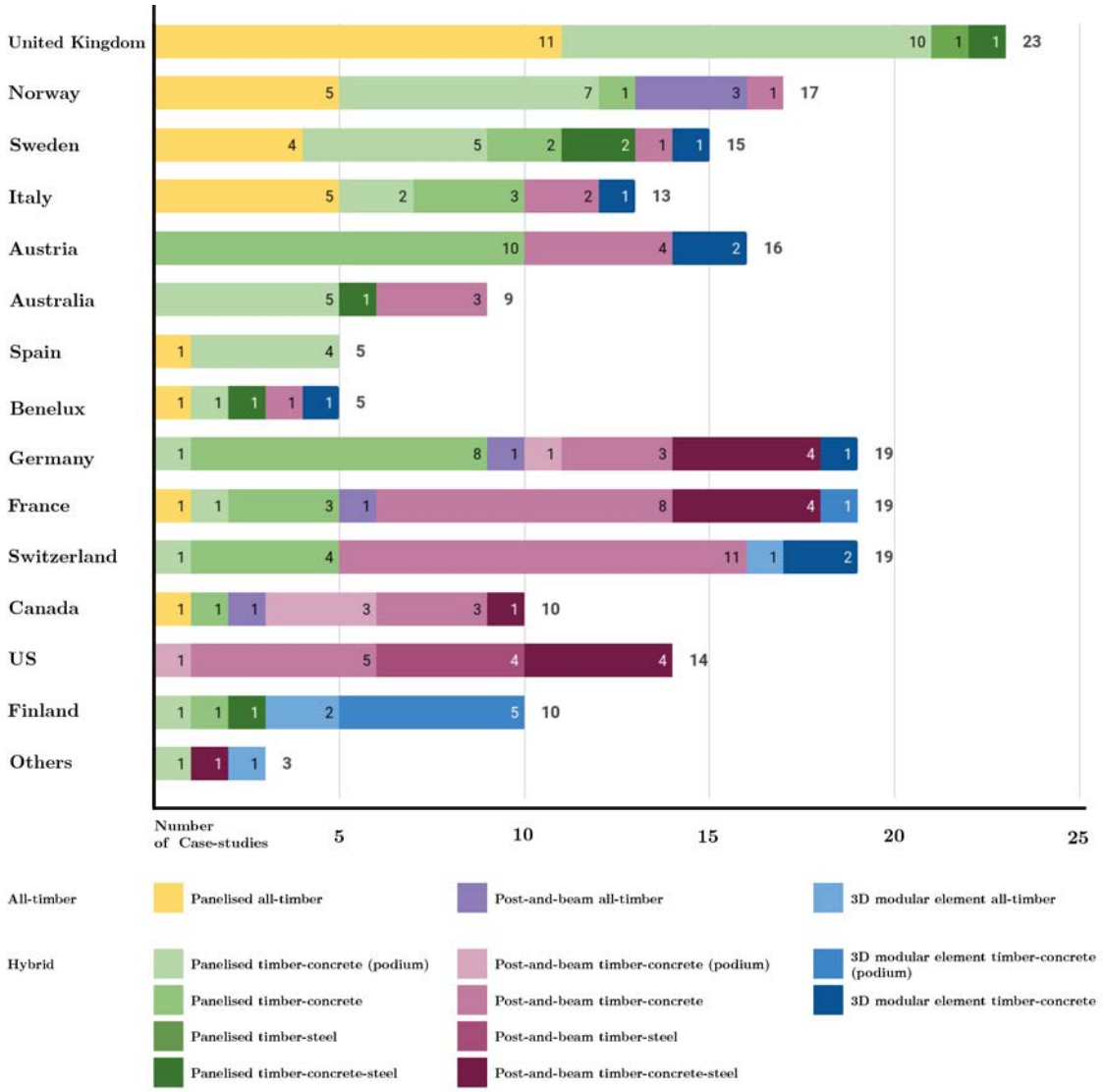

Figure 5.51: Structural categories per country

The analysis of the structural categories pointed out that the majority of the MTBs are hybrid buildings. As Figure 5.52 displays, 80,2% of all the selected case-studies have either a podium, a core, both, and other steel elements integrated in their structure. This confirms that in the tendency in the design of MTBs is to build *timber-based* buildings, and only a minority of them

have been designed with an all-timber structure (19,7%). On the other hand, 27,9% of the projects have an all-timber structure on top of a concrete podium.

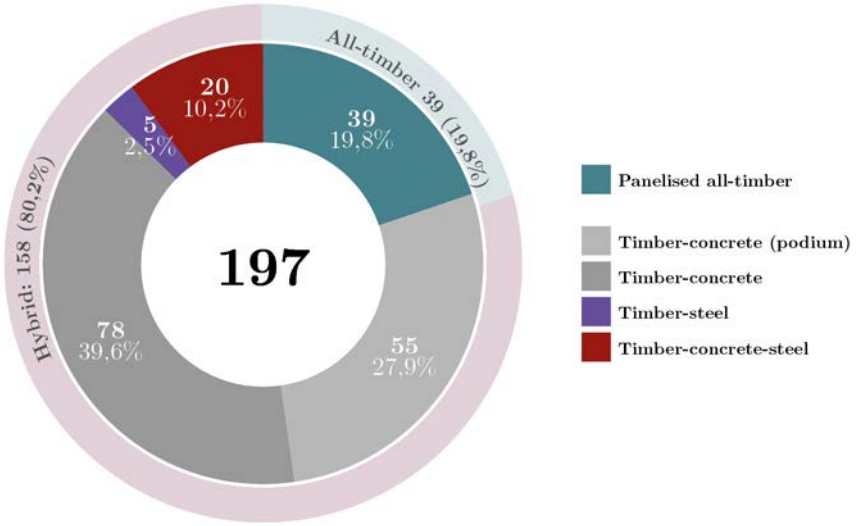

Figure 5.52: All-timber and hybrid structures

A different perspective is given by Figure 5.53 which shows the number of case-studies represented by the previously identified categories. In this case, the countries are grouped by their main regional area (Central Europe, Western Europe, Southern Europe, Scandinavia, North America, and other countries). In Figure 5.53 several observations can be observed:

- Panelised all-timber and Panelised timber-concrete (podium) are the two most frequent categories. If the first one is represented mainly by the UK, Italy, Norway and Sweden, the other one has a more heterogeneous number of countries and regions;
- The majority of Panelised timber-concrete (core and podium-core) are designed in Central Europe (mainly Austria and Germany);
- Panelised systems with internal timber frames (with and without podium) are present only in France and in Quebec (Canada);
- Panelised timber-concrete-steel (podium and steel rods) are only designed in Sweden and Finland;
- Panelised timber-steel (frame) is represented by the British project *Curtain Place. Wenlock Road 17-21* is instead the only project belonging to the Panelised timber-concrete-steel (podium and core) category;
- Post-and-beam all-timber (with timber bracing) are only designed in Norway, and they are the projects *Treet* and *Mjøstårnet*;
- Post-and-beam timber-concrete (podium) are mainly designed in North America, as many post-and-beam timber-concrete-steel categories. Post-and-beam timber-steel case-studies can

only be found in the US. Post-and beam-timber-concrete (podium and core) are more frequent in Central Europe, Western Europe, and in North America, especially in France and Switzerland;

- All the projects with a Post-and-beam timber-concrete (podium and timber bracing) structure were designed in Australia;
- *Te Ara Hihiko* (New Zealand) is the only case-study of the category Post-and-beam timber-concrete-steel with podium and steel bracing, and it represents a unique system described in Section 5.3.15;
- The French project *Opalia* is the only case-studies of the Post-and-beam timber-concrete-steel (core-steel beams) category, meanwhile the other two projects *Green Office® Enjoy* and *Kibori* are the only case-studies of the Post-and-beam timber-concrete-steel (core-bracing) category.
- Belonging to the same post-and-beam timber-concrete structure, the Swiss case-studies *Tamedia* and *Omega Headquarters* had some similar screw-less connections with the Norwegian project *Bjergsted Financial Park*;
- The majority of the Post-and-beam timber-concrete-steel (podium, core, steel beams) category are designed in Germany, and they are the *E3*, *C13*, *Famju*, and *Skaio* projects;
- 3D modular structures are more common in Finland, whereas the category with timber-concrete (podium and core) is typical in the Central Europe area.

Figure 5.53 portrays the heterogeneity of structural solutions which exists for MTBs. These observations presented before, identify some clusters of solutions related to specific regions or nations, proving that in several cases, MTBs are a national-based phenomenon. For examples, the specific approach seen in *Treet* and *Mjøstårnet* or in the German buildings similar to *E3*, are unique in the world context, and deserve a contextual research on the motifs of these singularities. However, the majority of the projects (135 case-studies) can be defined by one of six categories: Panelised all-timber, Panelised timber-concrete (podium), Panelised timber-concrete (core), Panelised timber-concrete (podium and core), Post-and-beam timber-concrete (core), and Post-and-beam timber-concrete (podium and core). On the other hand, 62 case-studies have a more specific solution, which might have more representation in the future.

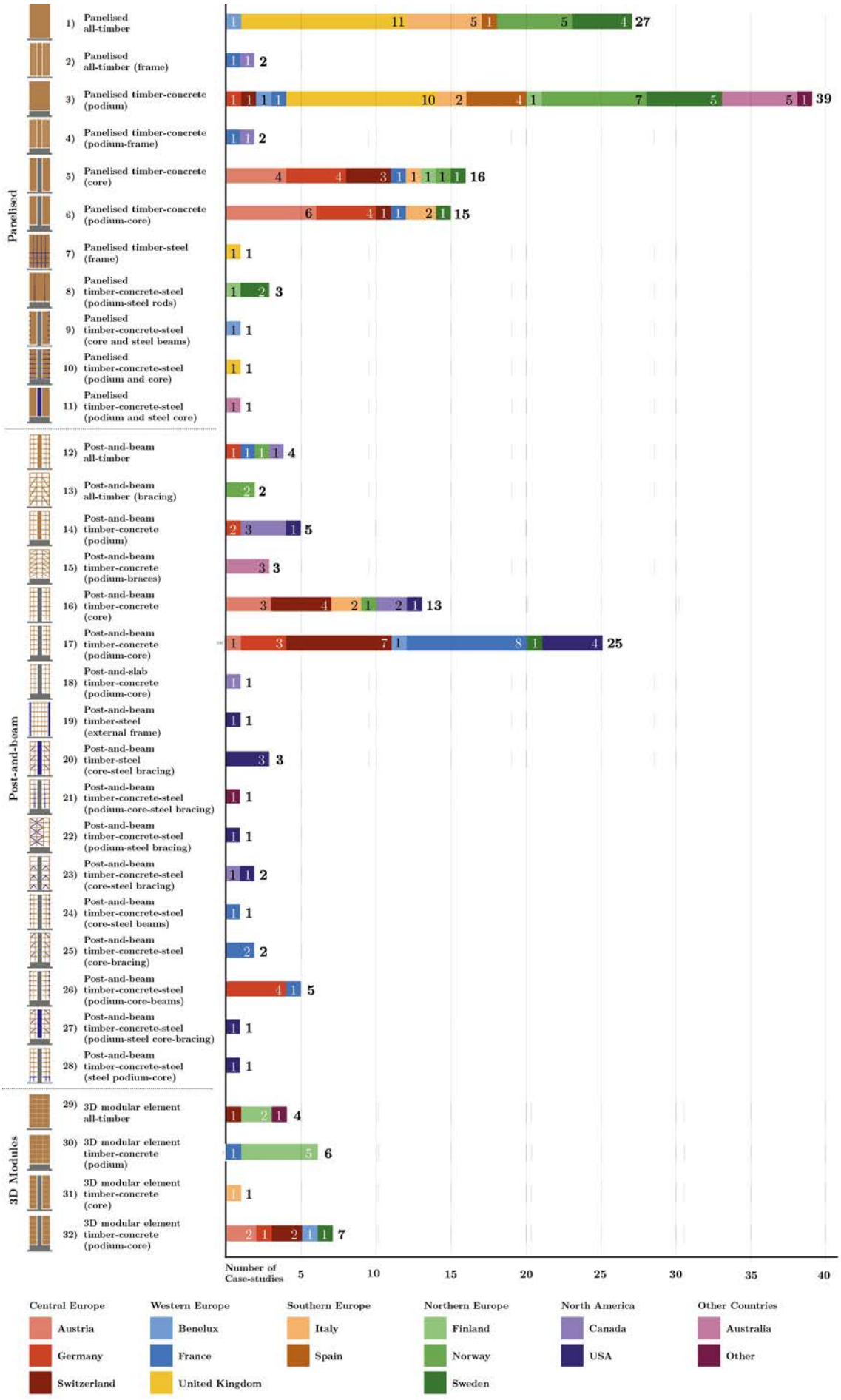

Figure 5.53: The number of case-studies per structural category, divided by country and world region

5.4.3 Structural Materials

Besides the structural categorisations, the survey also researched the materials used in the podium, the core and the floor slabs of the case-studies (see Figure 5.54). In this regard CLT emerges as the major trend in the construction of MTBs. Concrete is widely used in podiums and cores. However, these trends are not globally distinguishable, and there are some countries where few case-studies, or none at all, use CLT in their projects.

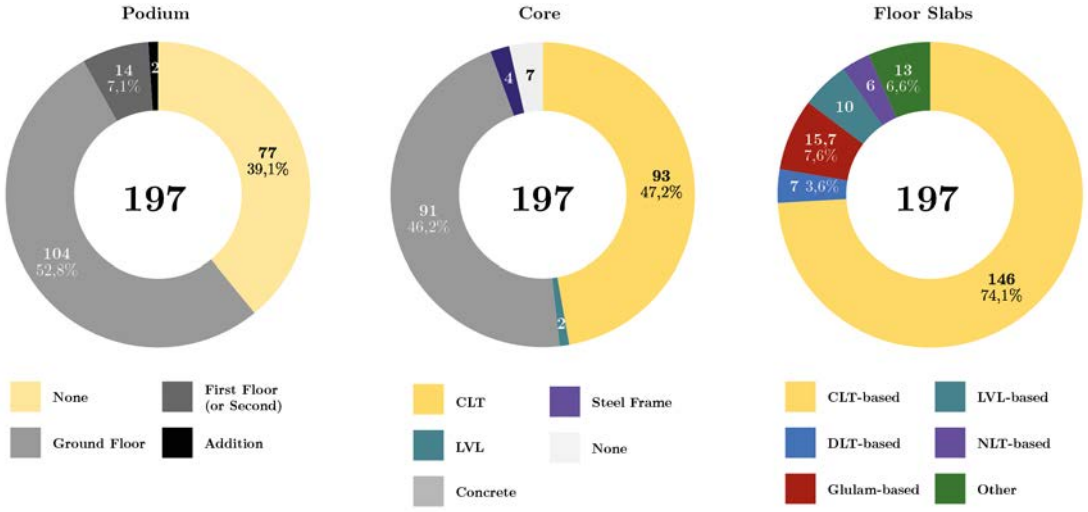

Figure 5.54: Trends of structural materials of MTBs

The majority of the buildings have a podium on which an all-timber or a hybrid timber structure is anchored (see Figure 5.55). In 52,8% of the selected case-studies, the ground floor is made of concrete and forms the podium of the building. Having a podium sometimes has a double effect: first, it raises the timber structure up in order to not be affected by insects and humidity problems, and secondly it gives it more flexibility when it comes to using the ground floor, which is often used as a space for retail. On the other hand, 39% of the case-studies do not have a podium, and their number of timber-storeys match the actual number of storeys. Except for two case-studies (*SZU-Betrisbgebaude* and *55 Southbank Boulevard*), the remaining 14 projects have a first floor (or in one case, a second floor) level podium. Only *Adohi Hall* had a steel podium. Figure 5.55 shows that Italy, Norway and the United Kingdom are the countries with the lowest number of case-studies with a podium, and Australia is the only country in which all case-studies have a podium.

The specific analysis of the buildings core shows that globally, CLT and concrete are equal in their usage as the main core material in the case-studies (see Figure 5.56). Few case-studies have alternative materials. Two projects in Finland have an LVL core, whereas four projects in the US have a steel frame on which the timber frame is connected. Seven projects do not have a core thanks to their post-and-beam structural solutions. CLT represents a global trend, however there are some countries in which it is not utilised in the majority, or any of the case-studies. Some countries like Switzerland, and Austria have only concrete cores (or none).

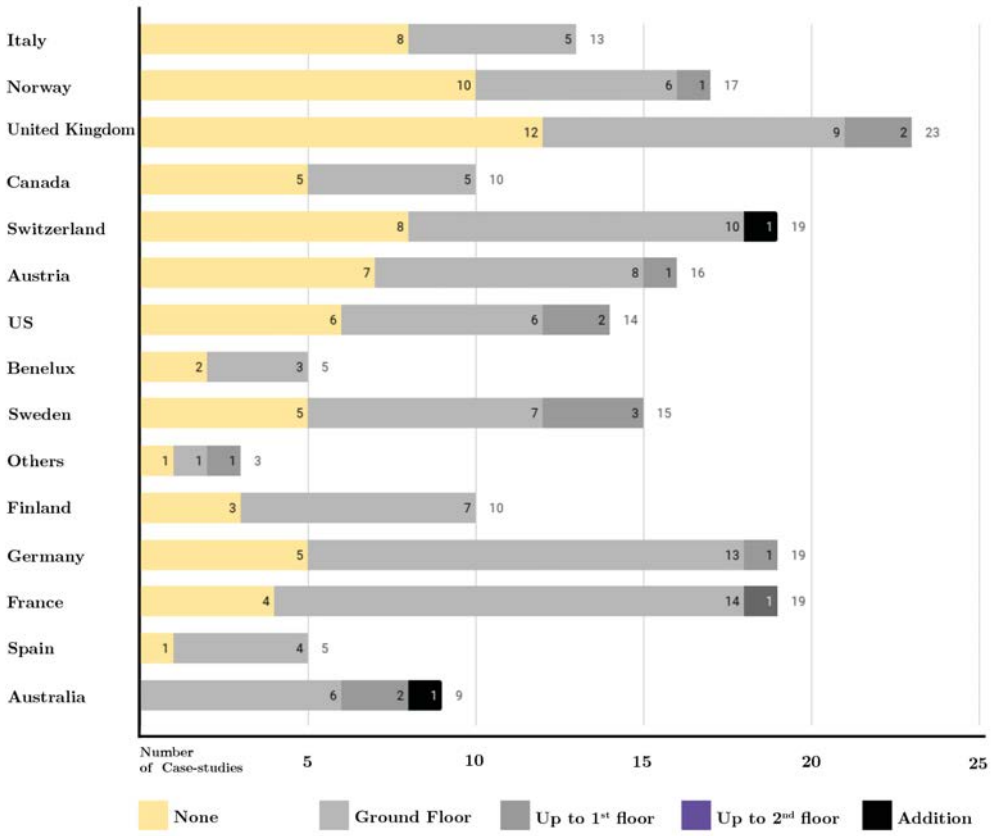

Figure 5.55: Presence of podium and podium heights per country

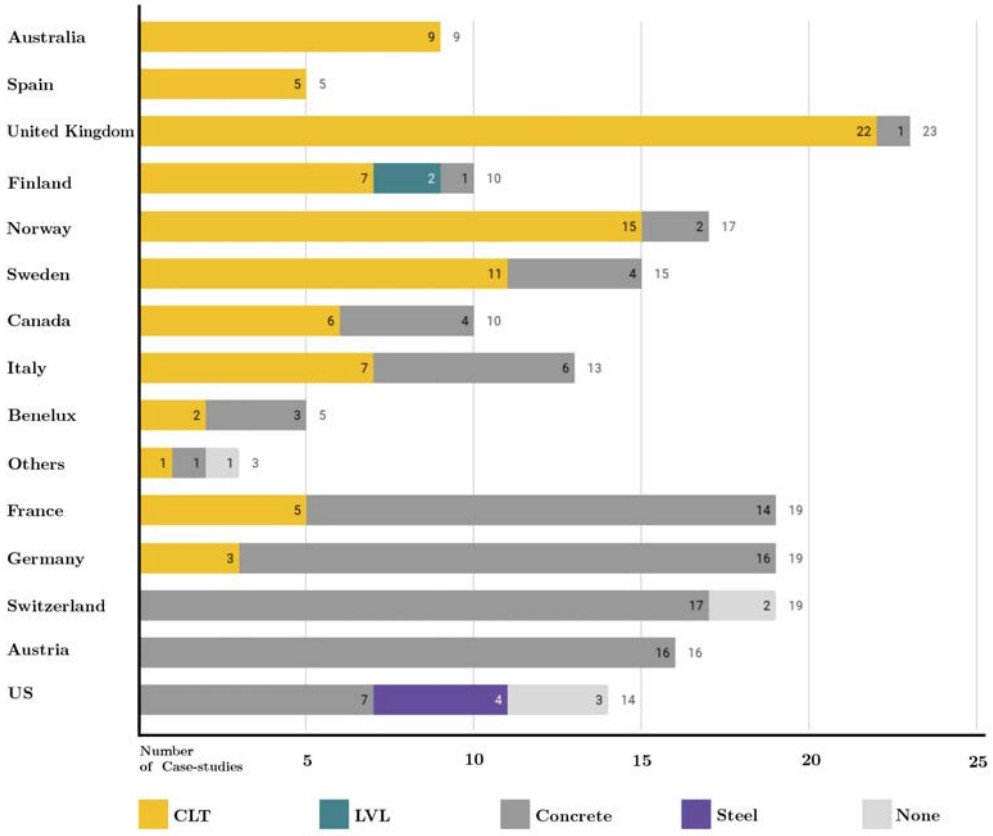

Figure 5.56: Core material per country

The United States has differing materials, mainly concrete and steel. Steel cores in particular are a specific structural solution used only in the US. The reasons for this and other differences will be researched in the next chapter.

Through analysing floor slabs, it became clear that the use of CLT has become a major trend. Only in the United States and Switzerland were other materials chosen in a higher number of case-studies. The United States is the only country where NLT is one of the most used material in the floor system. However, as shown in the country analysis, all the most recent US case-studies have CLT floors. Switzerland has a more heterogeneous set of options, with the majority of its case-studies adopting box-element floor slabs made of different EWPs. CLT-concrete combinations are frequent in Austria and some appear in Germany as well. The same countries, together with France and Switzerland also have case-studies in which glulam-concrete floor slabs are used.

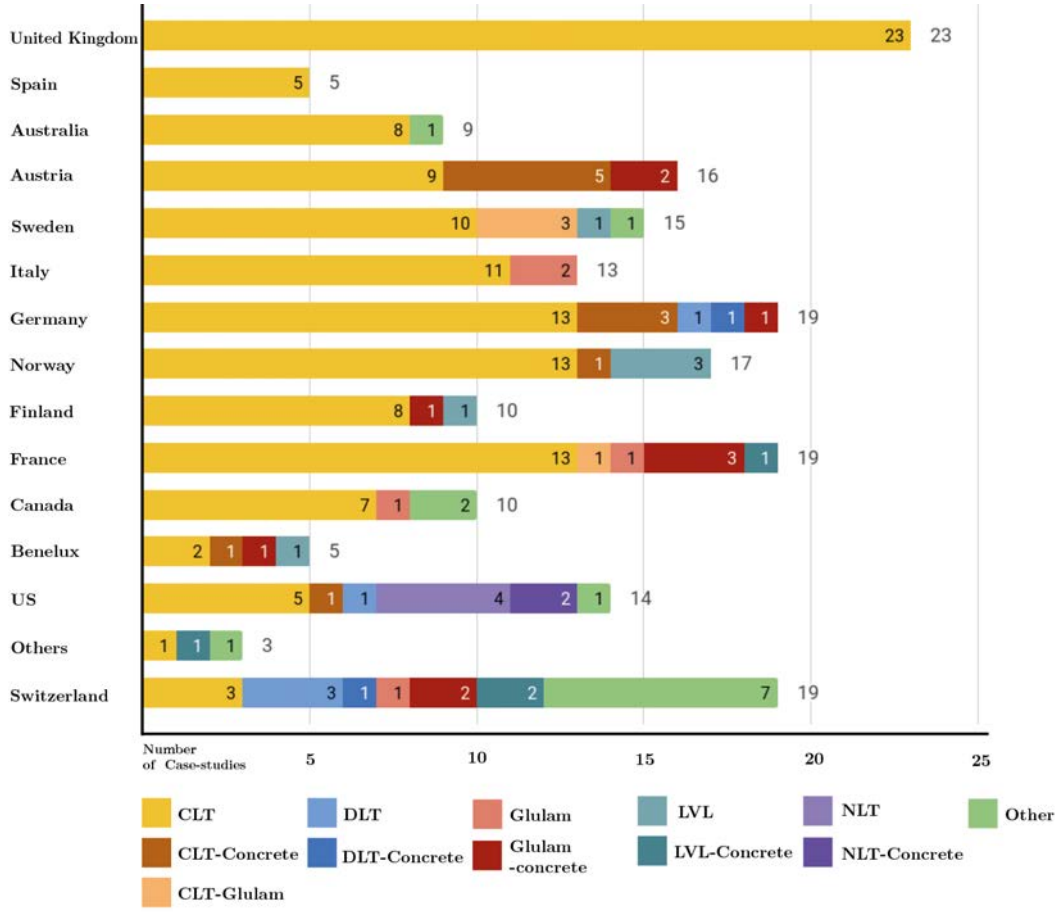

Figure 5.57: Floor slabs material per country

Through the analysis of the case-studies, it emerged that columns and beams are mostly made of glulam. Very few differences were observed in this regard. LVL beams were used in the Swiss offices *Suurstoffi S22* and *Arbo*. In the Norwegian case-study *Bjergsted Financial Park* LVL beams were used in the first floors and combined with glulam cover in the upper floors.

5.4.4 Considerations on the Heights of MTBs

The analysis of the projects also laid out the evolution in building height of the selected case-studies. Figure 5.58 shows that though the mid-rise buildings are the greatest in number, the height of the tallest projects grew progressively every couple of years. *Stadhaus* was the first MTB to reach nearly 30 meters, and it was surpassed by *Forté* in 2012. *Treet* in 2014, and *UBC Brock Commons* in 2017 both reached more than 50 meters and finally *Mjøstårnet* became the tallest MTB in 2019. As the number of MTBs has grown, especially over the last few years, so has their height.

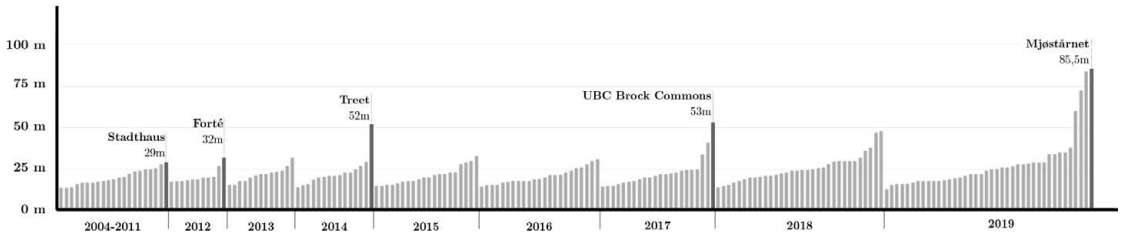

Figure 5.58: Height evolution of the case studies (2004-2019) and tallest examples

Figure 5.59 arranges the tallest projects together. These projects were built in different countries, with no country in particular having a considerable number of tall examples. These countries are Australia[2], Austria, Canada, Finland, France, Norway, and Switzerland. The Austrian *HoHo Wien* is the building with the highest number of storeys but is not the tallest: its height, at 84 meters, is slightly less than *Mjøstårnet*, which is 85.5 meters tall and makes the Norwegian building the tallest case-study. In the same figure it is also possible to see that some buildings have parts made of concrete or steel. The tallest project *Mjøstårnet* is an all-timber structure. All other projects except for *Treet* are hybrid buildings, with a concrete podium, a concrete core, or both. Of the ten tallest buildings, six are based on the post-and-beam system, and the other four on the panelised system.

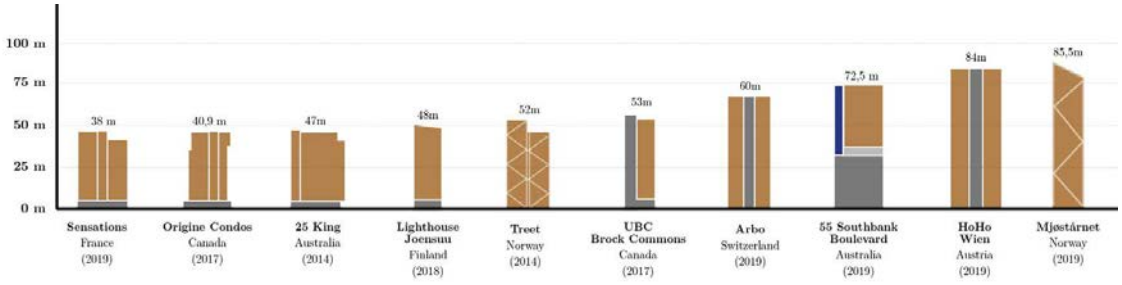

Figure 5.59: The ten tallest case-studies of this survey

[2]The building *55 Southbank Boulevard* was counted as a seventeen-storey building even if the actual timber storeys were ten.

Through the comparison of the main structural system in mid-rise and high-rise buildings no significant differences appear. Even if the first five tallest buildings have a post-and-beam structure, many high-rise projects like *Sensations*, *Origine Condos*, and *Lighthouse Joensuu* are all tall examples built with a panelised system. Even 3D modules are similarly represented in the high-rise projects, thanks to projects like *Hotel Jakarta* and *DAS Kelo*.

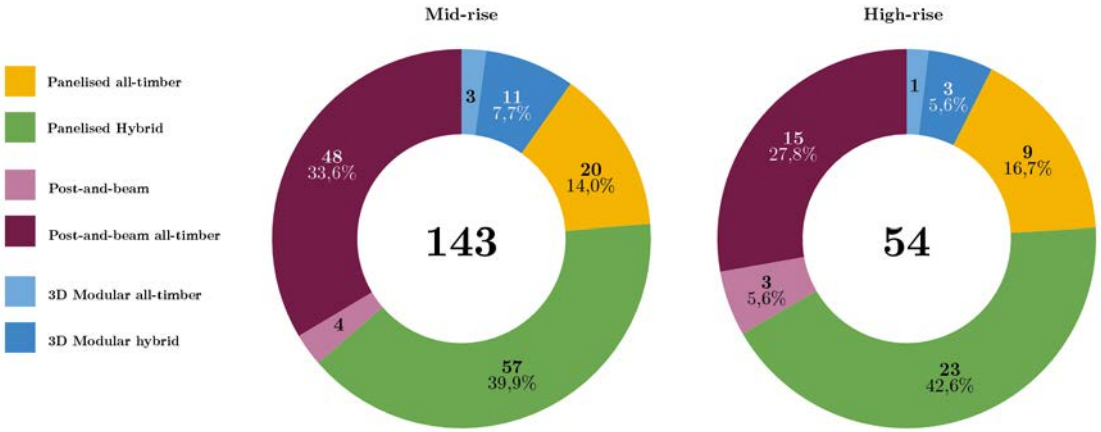

Figure 5.60: The ratio between the type of structures in the mid-rise and high-rise buildings of this survey

5.4.5 Technical Solutions According to the Structural System

The analysis of the case-studies revealed different technical solutions in order to solve key-structural issues in the design of an MTB. These issues were mainly the vertical load transfer to the foundations, and stiffening strategies. The solutions adopted in the case-studies usually depended on the structural systems the designers chose. Panelised buildings are mainly composed of details in which two-dimensional elements connect, whereas post-and-beam structures are more heterogeneous, and are involved in a wider range of one- and two- dimensional connected elements (like floor slabs, columns, beams, and core walls). Some technical details observed in the design analysis depended on the height of the buildings. Projects which were considered high-rise, had to solve some issues like the size of the bottom walls and columns, or the shrinkage effects of the transfer of loads to the foundations.

Figure 5.61 collects details from some previously described representative case-studies. In panelised structures, the load transfer connection from the load bearing walls and the floor slabs is usually resolved with the floor supporting the walls (see *Stadthaus* and *Cenni di Cambiamento*). In panelised projects, this detail is particularly relevant, and the structural engineers have to carefully consider the possible shrinkage effect that could affect the floor slabs, due to the weight of the building. This type of connection varies across projects. In these two cases, socket external connections were used in *Stadthaus*, whereas metal plates and self-drilling dowels were used in *Cenni di Cambiamento* (Kaufmann et al., 2018). An alternative example is given by *Dalston Lane*. *Dalston Lane* is taller than the other projects, and the designers opted for pouring concrete grout

where the load is transferred from the load-bearing walls and the floors. This decision was due to the shrinkage risk of the ten-storey project (Kemp, 2015) (Harley et al., 2016).

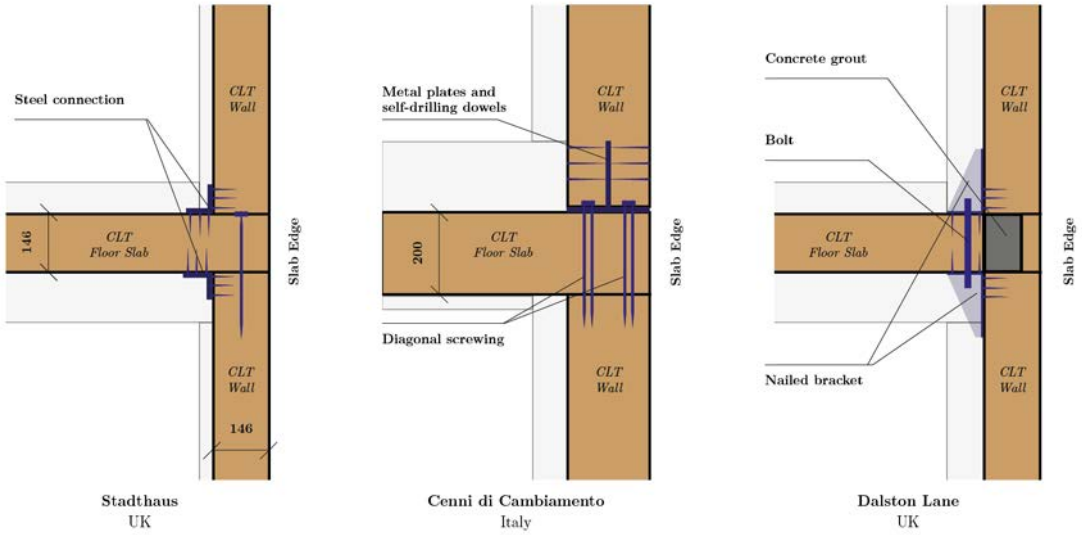

Figure 5.61: Vertical load transfer in panelised case-studies

In the post-and-beam structures, the vertical load transfer detail was solved in many ways. Figure 5.62 and Figure 5.63 reflects some solutions observed in the case-studies. *Life Cycle Tower* has hybrid concrete-glulam floor slabs which have integrated an edge concrete beam acting as the main connecting element to the columns. The floor slab is placed on the top of the column, which has integrated a steel tube. At this point, a non-shrink grout is poured inside the concrete edge beam around the steel tube. Then, the upper column is placed and connected with a steel connection inserted in the steel tube of the column below. To fix the elements, concrete grout is poured a second time.

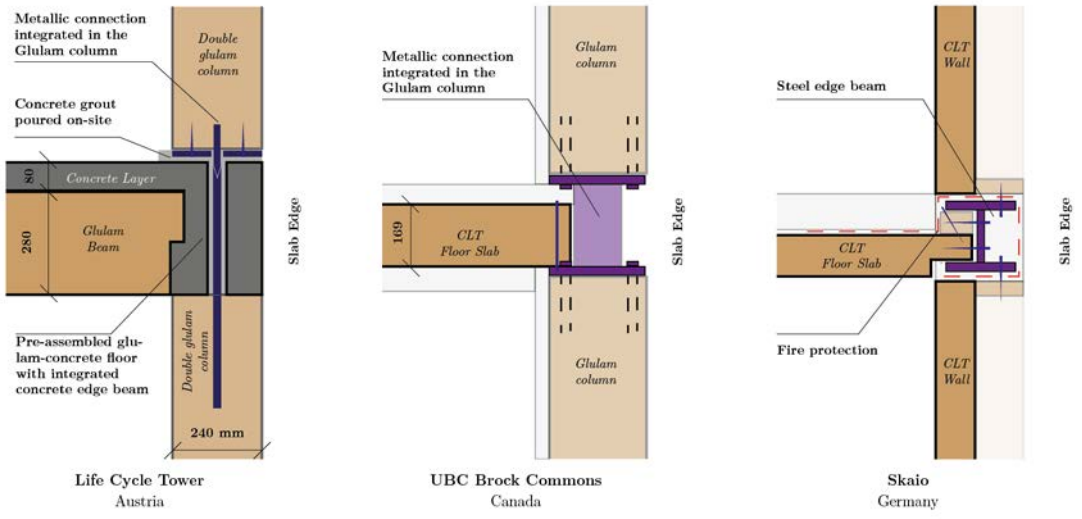

Figure 5.62: Vertical load transfer in post-and-beam case-studies

A different system was developed in *UBC Brock Commons*. In the Canadian building, a special connection in the top part of the column primarily supports the CLT floor slabs connected to it, and then allows for the connection to another column on the top of it. This technical solution is applied throughout the entire project, with no difference between the internal and the columns along the edge of the structure. This steel connection also allows the distance between the columns to be regulated, thanks to the screws. This facilitates the assembly, and it allows the element to be matched on site, with the required assembly measures. This allows it to have the highest degree of precision. In *Skaio*, the main load transfer connection is a steel edge beam on which CLT floors and walls are nailed. By using a steel beam, the designer had to protect the element with fireproof layers. In this case extra care was necessary, being that the CLT ceilings were left exposed.

As in *Life Cycle Tower*, as well as *HoHo Wien* a concrete edge beam is connected to the columns. The difference in this case is that the beam is made of precast concrete and is not integrated in the floor slab of *HoHo Wien*, forming instead a separate element. Additionally, this edge beam has two types of sections as Figure 5.63 shows.

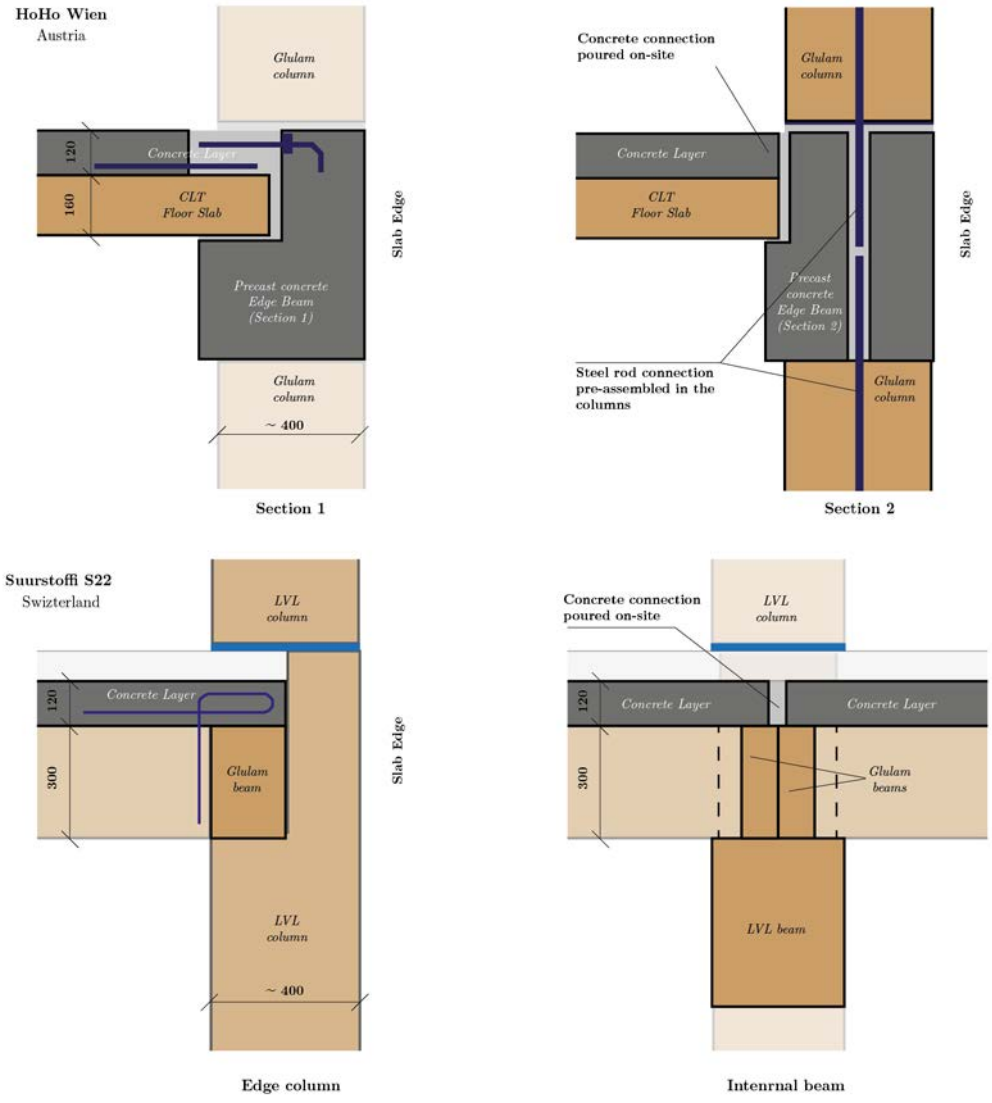

Figure 5.63: Vertical load transfer in *HoHo Wien* and *Suurstoffi S22*

The first part of the concrete edge beam of *HoHo Wien* (Section 1) allows the hybrid timber-concrete to be supported and connected. The pre-assembled steel rods in both the elements (floor slabs and edge beam) are then fixed with a concrete grout poured on-site. The other section of the edge beam (Section 2) connects the upper and lower columns. Some metallic plates create the space under the upper column in which a special concrete-based grout is poured on site once the elements have been assembled. The grout fixes the two columns and their steel tubes together inside the edge beam. Tolerances are adjusted on-site with the use of steel plates under the columns. In the case of *Suurstoffi S22*, two details were selected. A first one shows the connection between the hybrid glulam-concrete floor slabs and the edge column. Here, the floor slab is supported directly by the column, the top part of which is thinner, creating a ledge in order to create space for the pre-assembled floor. With this system, the bottom column is connected directly to the upper one. The remaining layers of the floor complete the connection. The other detail shows how an internal LVL beam supports the floor slabs. In this case, the LVL beam is connected to the edge of the LVL column, and the glulam beams of the hybrid floors lie directly on top of it.

Bracing systems are necessary in most post-and-beam structures which reach considerable heights, especially when they do not have a concrete core as LLRS. An example of these structures is *Mjøstårnet*. Its columns and beams handle the gravitational forces in horizontal and vertical direction and give the building its necessary stiffness. Figure 5.64 shows the slotted-in steel plate connection used to connect the glulam columns with the perpendicular and diagonal beams.

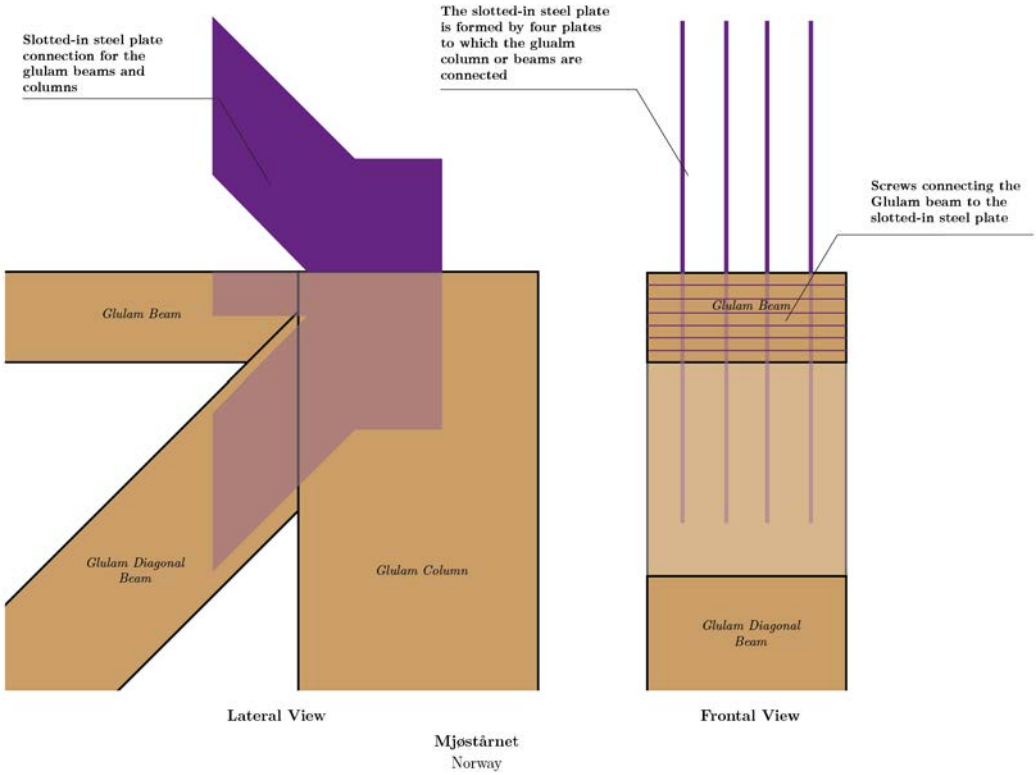

Figure 5.64: Steel connection in *Mjøstårnet*

This type of steel connection is a high capacity connection which is commonly used in bridges and large buildings, but the design team used it to assemble *Mjøstårnet*. The slotted-in steel plates are formed by several plates in which the columns or beams are inserted on-site and then nailed to them. This requires that the elements have to fit down to a millimetre. This speeds the erection, but require extra design care during the design and the production of the element. Additionally, the glulam beams and columns protect the steel plates from fire.

3D modular structures are more similar to panelised structures due to their composition of two-dimensional surfaces. Their assembly process is generally similar, having the operators connect 3D rooms on the top and near each other. However, some differences exist in the way the modules are formed and assembled. As we previously saw, some projects are all-timber structures, whereas some are hybrid timber-concrete. In the case of *Puukuokka*, the modules were formed by CLT walls and floor slabs. Once assembled in the building site, a bottom edge CLT foot, which runs all along the bottom edges of the 3D modules, lies on the top of the module beneath it. The space created is used for acoustic and thermal insulation. The 3D hotel rooms of *Hotel Jakarta* have instead a bottom part made of concrete. Their flat bottom surface is positioned on the top of the CLT walls of the modules beneath them. The top line of the CLT ceiling is not at the same height of the walls, and this allowed the designers to create space for a thin layer of insulation in-between the modules. The 3D modules of *Woodie* are assembled similarly as the ones of *Hotel Jakarta*. They are connected to the concrete floor of the corridor thanks to a steel connection, which is nailed in the concrete floor after the 3D module is placed beneath it. Another 3D Module completes the detail once it is placed on the top of the previous module, and in this way they are anchored together.

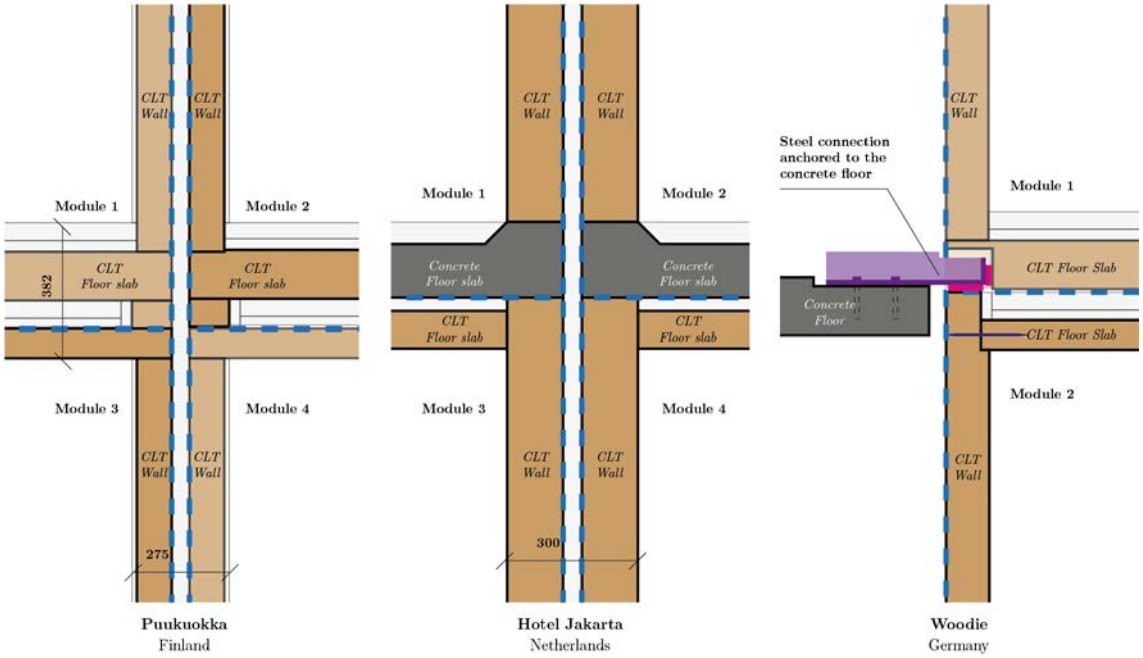

Figure 5.65: Assembly combinations in 3D modular element case-studies

There are many ways too to connect the floor slabs to the core. Figure 5.66 represents some solutions from previous case-studies. In *Life Cycle Tower*, the floor slabs have integrated an edge beam on two sides of the element, with one being connected to a steel support bracket already mounted inside the concrete core once erected. Because the glulam beams are left visible, a special fire protection layer had to be designed to protect the steel connection which supports them. The CLT floors of *UBC Brock Commons* are connected to the core in a similar manner. In this case, the CLT floors are nailed to the steel bracket already mounted in the core, as was done in *Life Cycle Tower*. The inside of the building is enveloped with gypsum boards, which also guarantee fire protection to the element.

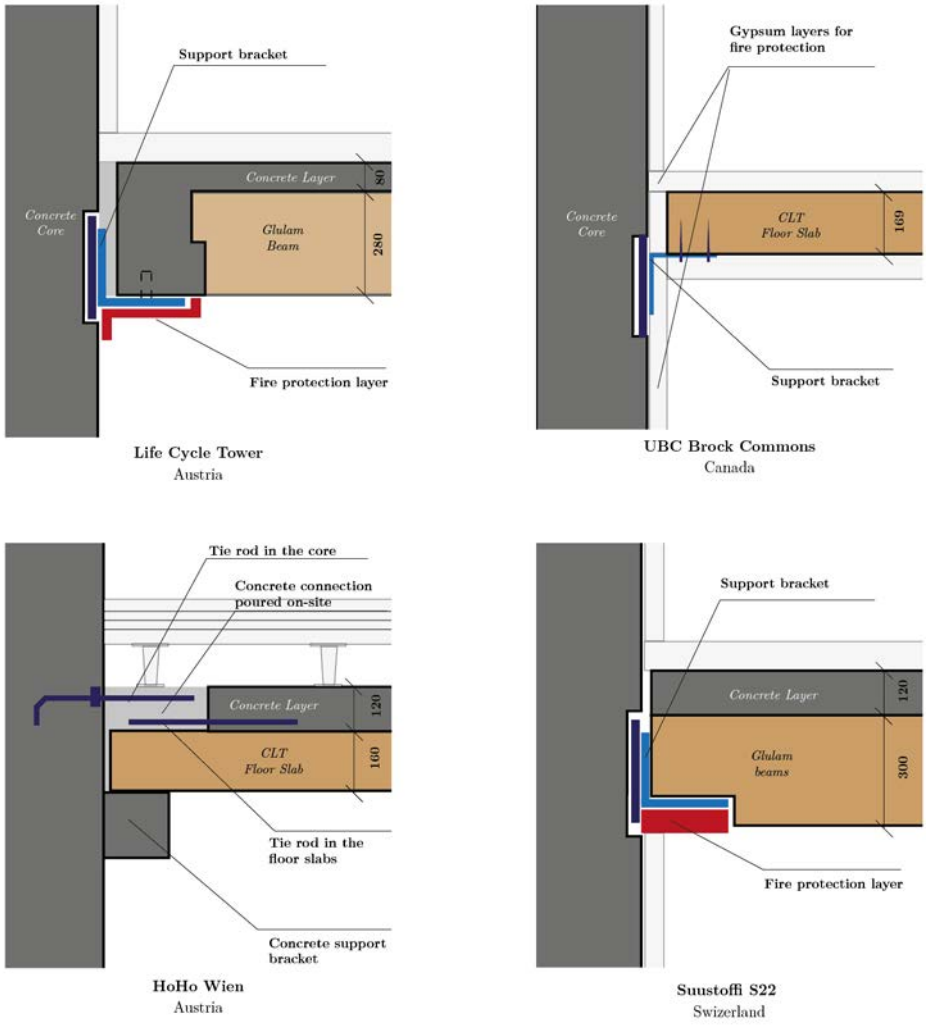

Figure 5.66: Edge details in panelised case-studies

In *HoHo Wien* a different solution was applied. The hybrid floor slabs are supported by a concrete support bracket connected to the concrete core. After having positioned the floor element, the detail is completed with a concrete connection poured on site, which connects two steel bars integrated both in the core and in the concrete layer of the floor slabs. The details of *Suurstoffi*

S22 are similar to those of *Life Cycle Tower*. The glulam columns are connected directly to a steel bracket inserted in the core which is protected by an extra layer of fire protection.

Floor to floor connections vary as well. In Figure 5.67 a few examples show possible solutions. In *Stadhaus* the CLT floors were nailed on the top of each other, whereas in *Cenni di Cambiamento* the CLT panels were nailed near each other with a series of diagonal screwing connecting them to each other. In *Life Cycle Tower*, the glulam-concrete floor slabs which lie between the columns and the core, were connected to each other with concrete poured on site once the floors were positioned. The floors of *HoHo Wien* are formed by two pre-assembled parts. The CLT floors are connected near each other as with *Stadhaus*, and the concrete layers are joined together by pouring concrete on site.

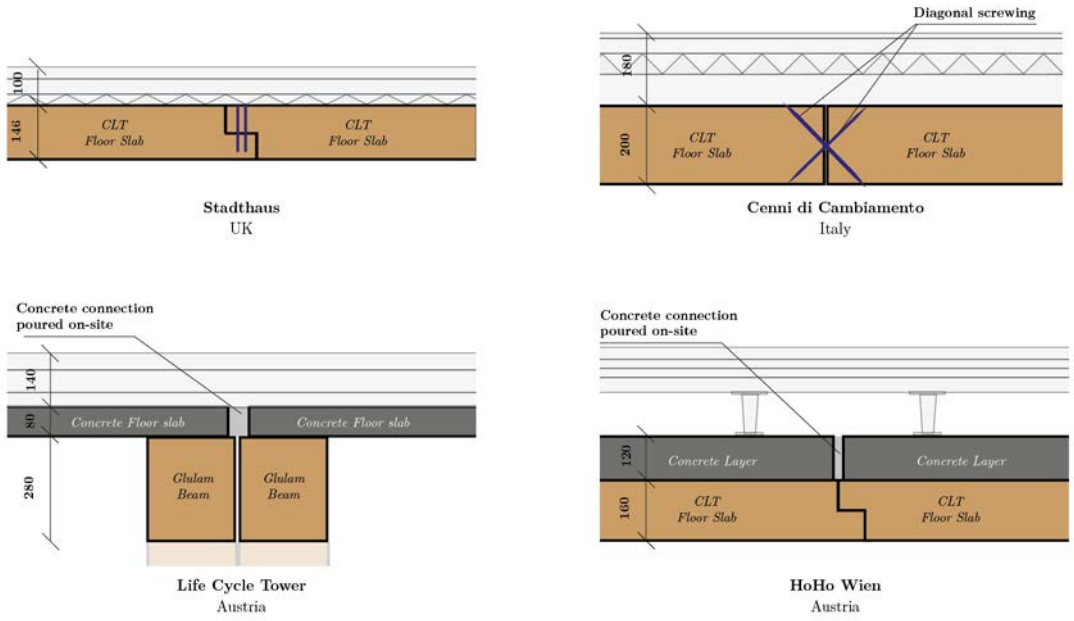

Figure 5.67: Floor connection in panelised case-studies

Some projects also showed that the floors can be assembled in other ways. As Figure 5.68 shows, in *Wenlock Road 17-21* the steel frame supports the floor slabs. The CLT panels are connected to a steel bracket which is attached to the steel beam. Gypsum boards are present in these projects to protect the steel frame from fire. *Wood Innovation Centre* has an all-timber post-and-beam structure, where the glulam frame supports floor slabs formed by CLT panels with different levels of thickness, and is positioned on the bottom or at the top of the floor section, in order to allow cables and pipes to run through. On the top of the glulam edge beam, the CLT floor continues and supports the facade.

The described details are just some examples of the existing possible solutions in the design and construction of MTBs. Regulations, fire strategy, structural systems, programs, and costs are some main influencing factors which can affect the final decisions made by the stakeholders, and a more detailed study is advisable for further research.

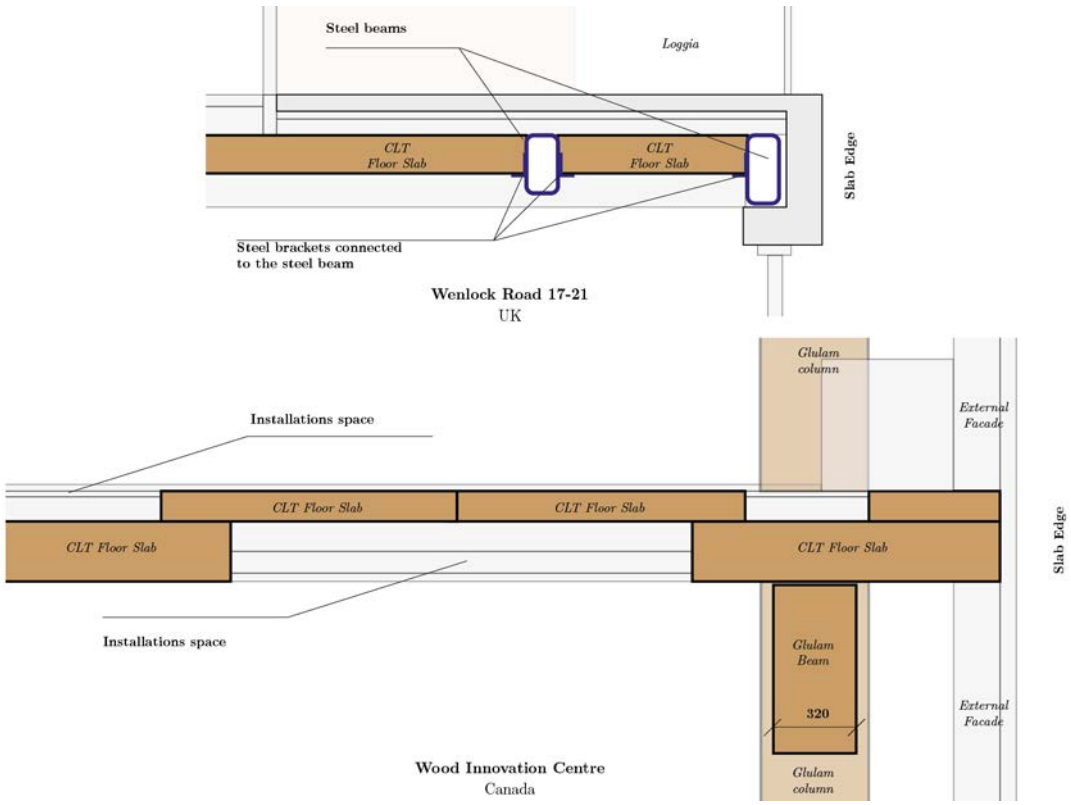

Figure 5.68: Floor slabs in *Wenlock Road 17-21* and *Wood Innovation Centre*

5.4.6 Other Design Differences

The structural analysis showed that there are several commonalities and differences between the case-studies and the countries. This will also be proven true in the case of results of the other design aspects analysis.

Globally, the most common program is residential. Other frequent programs are office and student housing. All the others (education, hotels, hospital, and senior living) have few examples or only one example. However, as for the previous analysis, also in this case the general tendencies are not applicable in every country. The United States is the country with more office case-studies than residential (or mixed use residential-office). The same is valid for France, where the majority of the case-studies are office buildings (double than residential). Norway has the highest number of student housing projects, which represent the majority of its case-studies.

Several countries like Austria, Germany, Italy, Switzerland, and Spain have a considerable number of social housing projects in relation to the number of residential buildings, proving that in some countries MTBs can also be accessible for these types of buildings. In Germany in particular, several projects were realised with a co-housing principle in which the group of clients opted for investing in timber. Other countries like Australia and Austria have a highly differentiated program palette, with many programs. On the other hand, countries like Finland or Sweden, have mainly one type of program built. In this regard, it was not clear to the author if the residential projects in these countries were to be considered social housing, as they were unspecified in most cases.

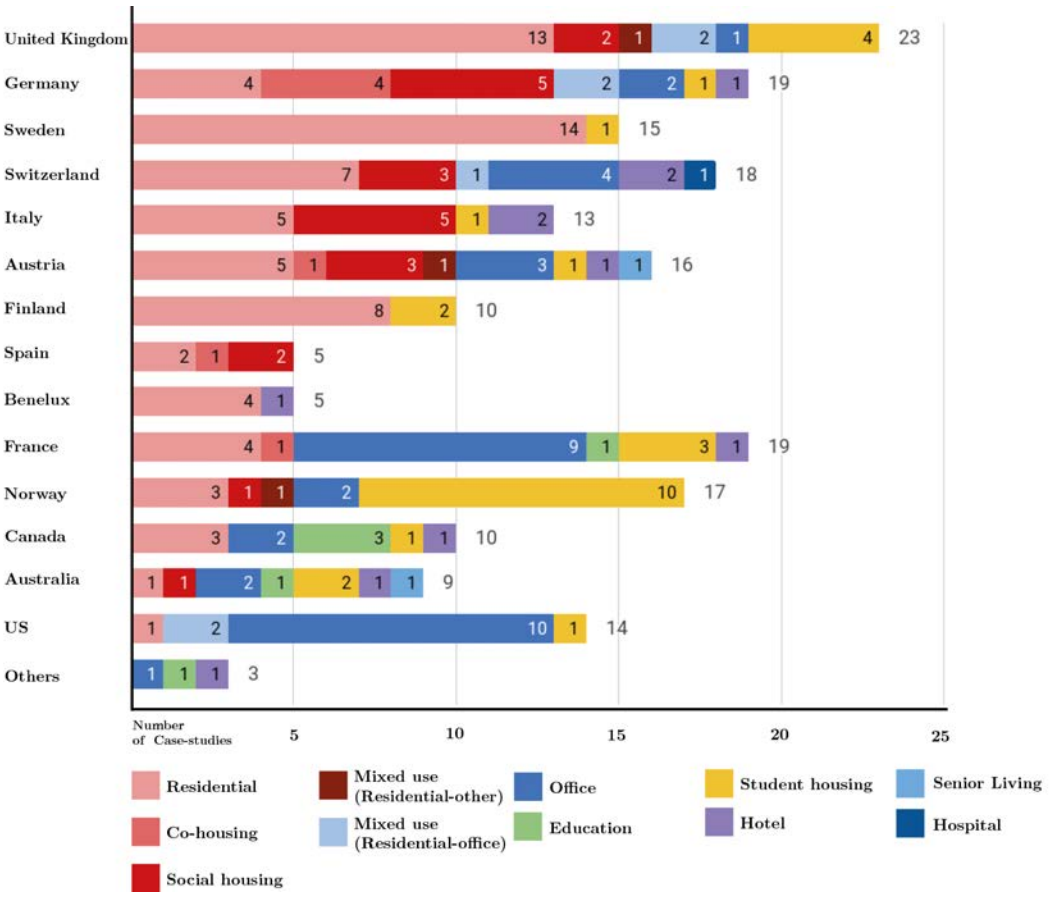

Figure 5.69: Program per country

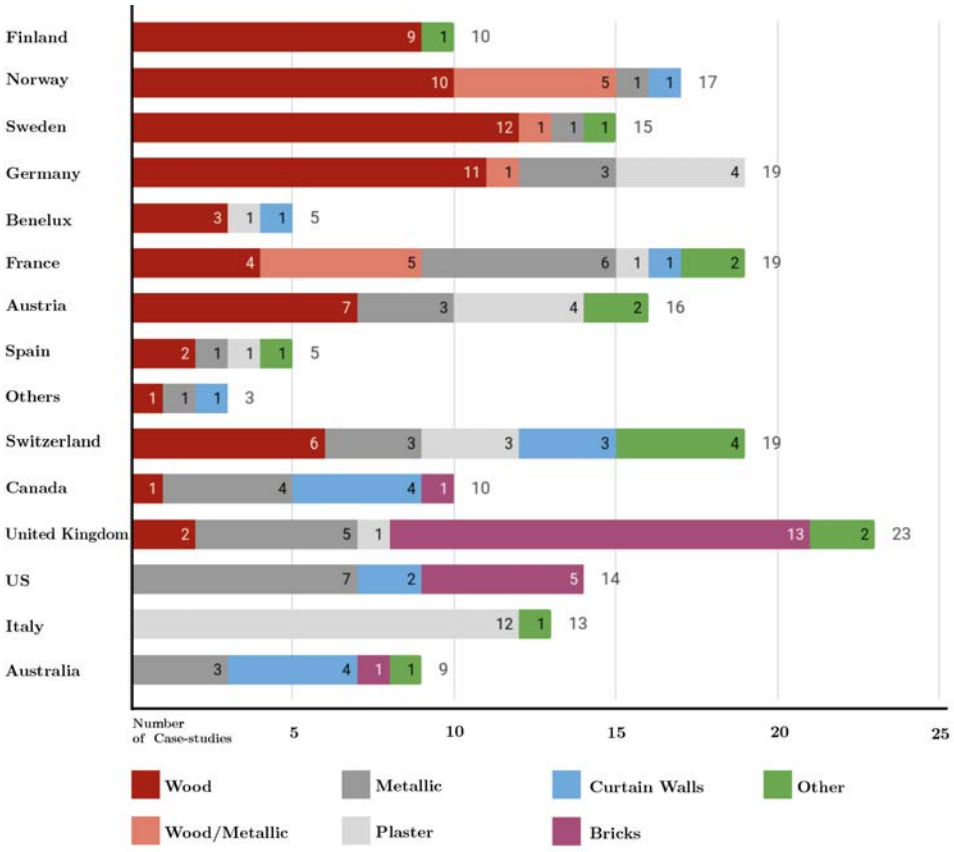

Figure 5.70: Facade material per country

Figure 5.71 shows the relationship between the structural system and program. The majority of the panelised systems have residential buildings, with several student housing projects as well. On the other hand, the vast majority of the office projects have a post-and-beam structure, with only *Green House* and *WoodTek HQ* having a panelised structure. Educational projects are also always designed with a post-and-beam structure. Residential, student housing and hotels are the most represented programs in the 3D modular element structure. Figure 5.71 also shows that residential projects can be designed in all the different structural systems, as student housing.

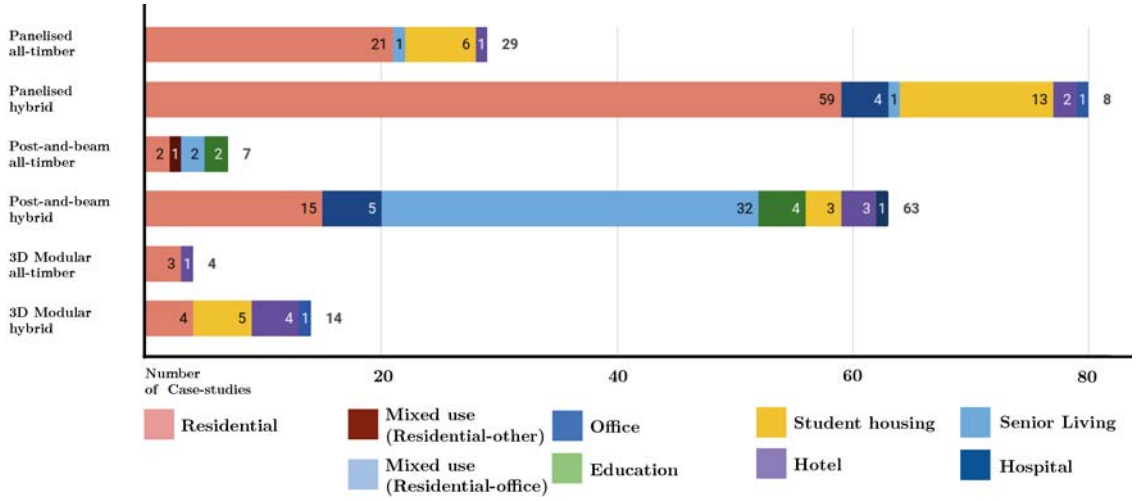

Figure 5.71: Distribution of the program in relation to the structural systems

The goal in analysing the exterior cladding was to research if there were correlations between the structure of the building and the visual appearance. The data collected in Figure 5.70 shows that each country envelopes MTBs in different ways, and there is not a vastly prevailing material. Wood boards (or shingles) are overall the highest percentage in some Scandinavia and Germany, but the other countries have more heterogeneous choices. For example, the Italian case-studies are mainly covered with plaster, and none of the projects have a wooden cladding. Australia and the United States do not have a case-study with a wooden facade and Canada has only one case-study out of ten projects. The majority of the British case-studies have a brick cladding. Therefore, the selected case-studies can appear differently according to the country in which they are built, and only in a few countries does there exist a correlation between timber-structure and visual timber appearance.

In regard to the indoor exposure of the structural elements there are differences between the countries as well. The general trend leans toward the exposure of some structural timber surfaces. 40% of the built case-studies are all enveloped in gypsum boards, the other 32% of the selected projects expose the majority of them. Nearly 10% of the case-studies only have the columns and beams exposed, and 7% have the walls exposed. Figure 5.72 shows that the United States is the only country where all the case-studies have their main structure exposed (it is also true that all the buildings have a sprinkler system).

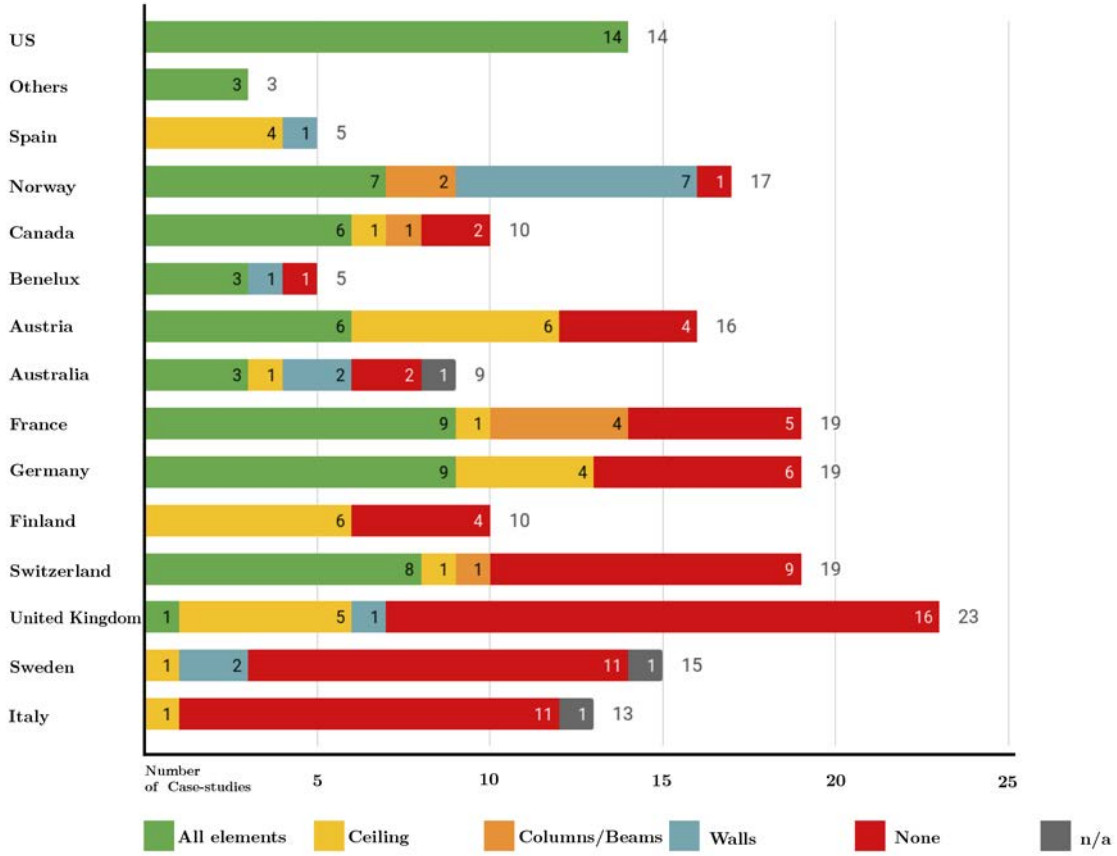

Figure 5.72: Indoor timber exposure per country

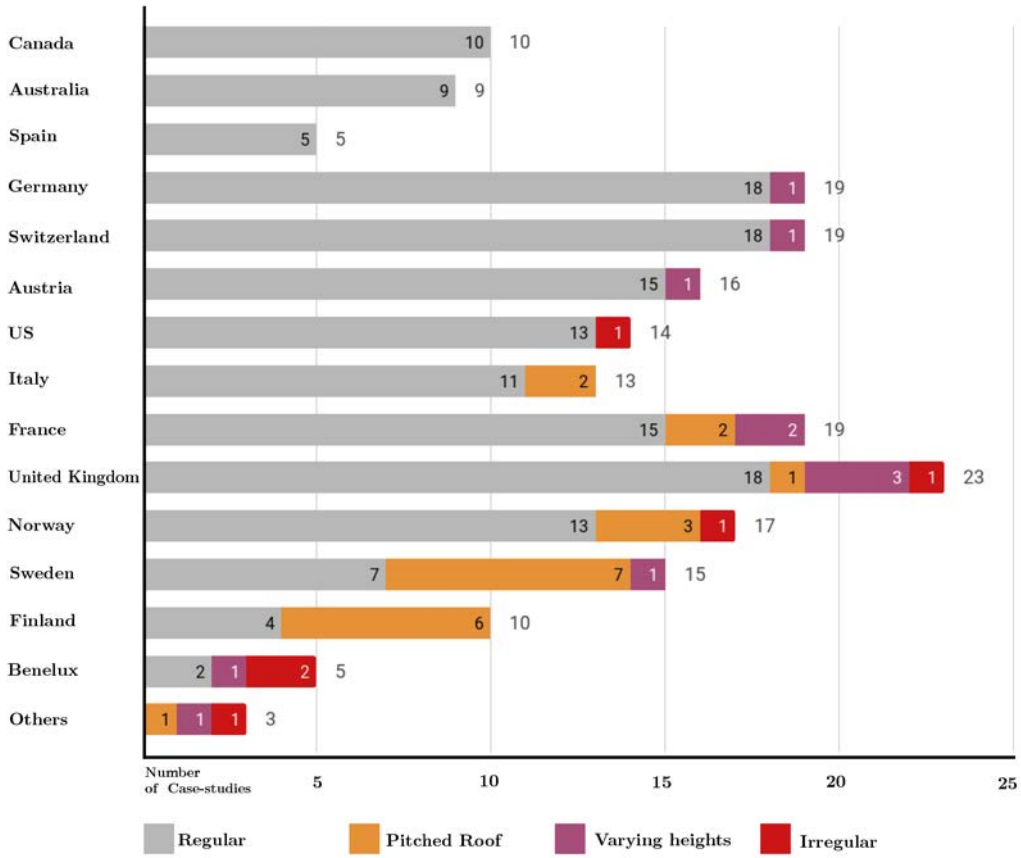

Figure 5.73: Building volume per country

In the rest of the countries, the case-studies with all their structure exposed are still the minority but in some countries, the cases are nearly half, such as in France or Switzerland. Partial encapsulation is a third strategy, especially in Australia, Austria, Germany and Norway. In Italy and in Sweden timber is practically never visible inside the case-studies except for a few examples, which leave the structural timber only partially exposed. Most of the time the decision to not expose the structural timber surfaces is influenced by each country's building code fire-requirements. More insights will be given in the next chapter.

As mentioned in Chapter 2, there are several benefits of exposing wood in the interior of the building. Most of the time concrete and steel structures do not have their structural elements exposed, especially in tall buildings. Encapsulating the structure of a building is not uncommon in traditional construction. The challenge of exposing the structural elements is fairly new for both the designers and authorities, and the beauty and the benefits of timber are coupled with difficulties in complying with fire-safety standards.

Finally, through the analysis of the architectural mass of the projects (see Figure 5.73), it appears that the majority of the buildings have simple volumes and regular plans. No complex volumes were built, except some particular cases, described as "irregular". What emerges from the analysis is that generally speaking, MTBs are simple volumes, as evidenced also by (Kuzmanovska et al., 2018). Exceptions are rare, and there are case-studies which tried different approaches. Case-studies which presented a considerable degree of complexity have a hybrid structure (like *Wenlock Road 17-21*), or are small buildings (like *WoodTek HQ*). Figure 5.73 also show that it is typical for the Swedish and Finnish case-studies to have a pitched-roof.

5.4.7 International Trends and National Nuances

This chapter analysed the case-studies both on a global perspective, and on a country perspective. In the first approach the global tendencies were highlighted, but the second analysis showed that these tendencies are not true in every country, and some differences do exist which make it hard to define MTBs as a globalised phenomenon. Below, the main findings of this chapter have been collected:

- Considering the 197 case-studies all together, mid-rise projects are three times more common than high-rise buildings. In the country-based analysis this tendency can be observed in the majority of the countries, but there are some exceptions (like France and Canada) in which the ratio is not so evident. Australia and Sweden have more high-rise projects than mid-rise.
- Through the analysis of the number of single case-studies (197), it emerged that the country with the highest number of built case-studies is the United Kingdom. Different analysis showed that there are many other countries which appear as forerunners in the global scenario. The case-studies are for example formed by several individual buildings, which considered all together, make the sample analysed reach the number 272. With this perspective, Nor-

way and Sweden have the highest numbers of built individual buildings. The top countries change again if the countries are arranged by the square meters (total and for every 100,000 inhabitants). In that case, Switzerland and Norway emerge as the top countries, followed by many others with similar numbers. These findings show that the number of case-studies is not the only relevant factor when analysing the countries, but the majority of the countries can be considered in the forefront of the design of MTBs.

- An MTB can be built according to different structural categories. From a global perspective, the most common structures are panelised systems. Post-and-beam categories were observed in nearly 35% of the case-studies, and 3D modular elements represent a small slice. However, these tendencies are not valid in all the countries. Some countries have a much more heterogeneous ratio between the structural categories. Some, like France, Switzerland, Canada and the United States, have prevalent post-and-beam systems. Finland is the only country with a prevalent 3D modular system.

- The structure analysis also proved that the vast majority of the selected case-studies have hybrid structures. Only 20% of the selected case-studies are considered "all-timber", and this supports the more inclusive term *timber-based* chosen in this dissertation.

- The division of the nationality of the case-studies according to one of the 32 structural categories defined in this dissertation proved that the majority of them can be included in six categories. Some categories are more representative of a country or a world region than others. Others can be found only in a specific country or are prevalent in a world region. This resulted in the identification of national or regional clusters of solutions.

- Most of the time, the core of an MTB is made out of CLT or concrete. This tendency can be different depending on the country. Some countries like Austria, have the majority or totality of the case-studies with a concrete core. Others, like the United Kingdom, have the opposite occurrence.

- Most of the buildings have a podium made of concrete. The majority of the podiums form the ground floor of the buildings, and they are also made of concrete. There was only one case-study in which the designers planned a steel podium.

- These differences continue in the analysis of the floor slabs. CLT is again the most predominant material for the floors in the majority of the countries. However, the United States and Switzerland have more heterogeneous floor slabs, with CLT floors appearing in only a few case-studies.

- The tallest case-study is the Norwegian building *Mjøstårnet* which is 85.5 meters high, and an all-timer structure. *Mjøstårnet* is followed by other tall examples which reach considerable heights, all having a hybrid structure (except *Treet*).

- The majority of the projects are residential. This global tendency is not true in all the countries, and several have more heterogeneous programs. In France or in the United States,

"office" is the most frequent program whereas Norway has a predominance of student housing projects.

- Office buildings are for the most part designed with a post-and-beam structure, whereas 3D modular element buildings have mainly a residential, student housing, and hotel program. Residential and student housing are designed in all the different types of structural systems.
- The facade cladding is generally heterogeneous, but the majority of the countries have specific materials. Scandinavian countries and Germany have wood as the main cladding material. The United Kingdom is the only country where the predominant cladding is brick.
- Partial exposure of the timber structural elements is the main indoor strategy. However, some countries have the majority of their case-studies' structures enveloped in gypsum boards.
- Finally, the building volume of these buildings is generally simple. Only a few case-studies were designed with complex geometries

Table 5.16: International trends and national nuances in the design analysis

	Type *(mid- or high-rise)*	**Strucutral system** *(category)*	**Core** *(material)*	**Podium** *(category)*	**Floor slabs** *(material)*	**Program** *(category)*	**Cladding** *(category)*	**Exposure** *(category)*
Austria	Mid-rise	Panelised	Concrete	None and ground floor	CLT	Residential	Heterogeneous	All or partial
Germany	Mid-rise	Panelised and P&B	Concrete	Ground floor	CLT	Social housing	Wood	All or partial
Switzerland	Mid-rise	Post-and-beam	Concrete	Ground floor	Other	Residential	Heterogeneous	Half exposed, half none
Benelux	Mid-rise	Panelised	Concrete	Ground floor	CLT and CLT-concrete	Residential	Wood	All
France	Nearly equal	Post-and-beam	Concrete	Ground floor	CLT	Office	Metal	All or partial
United Kingdom	Mid-rise	Panelised	CLT	None	CLT	Residential	Bricks	None
Italy	Mid-rise	Panelised	CLT	None	CLT	Residential	Plaster	None
Spain	Mid-rise	Panelised	CLT	Ground floor	CLT	Residential	Heterogeneous	Partial
Finland	Mid-rise	3D Modules	CLT	Ground floor	CLT	Residential	Wood	Partial
Norway	Nearly equal	Panelised	CLT	None	CLT	Student housing	Wood	All or partial
Sweden	High-rise	Panelised	Concrete	Ground floor	CLT	Residential	Wood	None
Canada	Mid-rise	Post-and-beam	CLT	None and ground floor	CLT	Heterogeneous	Heterogeneous	All
USA	Mid-rise	Post-and-beam	Concrete	Ground floor	CLT and NLT	Office	Curtain wall	All
Australia	High-rise	Panelised	Concrete	Ground floor	CLT	Heterogeneous	Curtain wall	All or partial
Other	Mid-rise	Heterogeneous	None	None	CLT	Heterogeneous	Heterogeneous	All
Trend	***Mid-rise***	***Panelised***	***CLT or concrete***	***Ground floor***	***CLT***	***Residential***	***Heterogeneous***	***Partial***

Table 5.16 collects these major findings by country and the "General" row indicates (when evident) the tendency regarding the analysed categories. There are some evident trends in the global construction of MTBs, but at the same time there are national nuances when it comes to specific design choices. In Table 5.16 the countries are positioned near the other countries traditionally considered in the same regions (Central, Western, Southern Europe, North America, and other countries). By doing this, it is possible to compare the common practices, but also to see that in some cases the countries differ in some specific aspects. With this analysis, it is fair to say that MTBs are more of a national phenomenon, and including them in general groups is not recommended.

5.5 Conclusions

This chapter answered the main research question: how were MTBs designed? The literature review on design surveys first evidenced a lack of comparative studies regarding built projects. Few studies compared a wide range of categories of design aspects and most of them focused on the structural categorisation of the projects. Following this path, the existing structural categorisation were enriched with hybrid categorisations and by the analysis of the main LLRS of the projects. Thirty-two different structural categories were introduced for the structural analysis of the selected case-studies. In parallel, other structural design aspects like the core, the podium, and the floor slabs were also analysed. Program, external cladding, interior timber exposure and analysis of the complexity of the building volumes of the case-studies were additional points of analysis which were considered other design aspects to consider.

Having set the survey design categories, this chapter proceeded with the analysis of the case-studies in every country, highlighting the most representative case-studies, and observing the commonalities and differences of the selected case-studies within each country. The main data analysed were collected at the end of each country's section. There is a wide variety of completed projects, and each country has similarly designed projects with some technical solutions used in case-studies in other countries. Similar design solutions were also observed between case-studies of other countries.

In the final section, all the global design findings from the selected case-studies were summarized and compared. It emerged that there are international trends in the design of MTBs, such as the choice of CLT for the material of the floor slabs, the choice of CLT or concrete for the material of the core and the prevalence of residential buildings. There are also national nuances, and countries which are located in a similar world region might share some similarities in the construction of MTBs, but there are always some differences between each single country depending on the analysed category. The result of the analysis proved that building MTBs does not look the same in every region and as hypothesized, there are relevant design differences.

Chapter 6

Context Analysis

Chapter 4 showed that there are national differences in the number and the completion years of the case-studies: some countries have a higher number of the built case-studies, and some realised these buildings in different years. Furthermore, Chapter 5 showed that on one hand there are international trends in the design of MTBs, and on the other, there are several national differences. One example of these differences are the prevailing structural systems and EWPs used.

In light of the findings, the goal of this chapter is to research the context in which the selected case-studies were built, in order to understand what were the reasons for the similarities identified by the design analysis. In this dissertation, "context" is the group of factors which may have influenced the realisation of an MTB. The regulatory framework, the professionals involved, the client, the universities and city councils, the industry which manufactured and supplied the timber elements: all are part of the context and can also be seen as drivers of MTBs. The literature on the drivers is heterogeneous, and the most studied topic is the influence that the regulatory framework plays. The analysis of the literature also shows evidence of the lack of a global comparative study of the stakeholders involved in the design and construction of MTBs. Additionally, the literature is focused on the barriers that limit the realisation of MTBs. Some of the reasons for projects being built as they are, were building height restrictions or concrete cores as requirement. Some projects were not built due to lack of know-how, and additional costs. Who decided to build an MTB and the motivations behind this decision, have not been researched with a global perspective. For this reason, in this study, a special focus is dedicated to the network of stakeholders involved in each MTB selected, along with the client's motivation and the type of public or private influences affecting these projects.

As the previous chapter, this part is built as a comparative survey in which several categorises of analysis are applied to the case-studies. The analysis first researches the overall influence on the completed projects (public, private, or both) and then identifies which kind of commission the building was realised (competition or direct). The analysis of the clients and motivations concludes the first part of the analysis. Another part is dedicated to the analysis in the network of the

stakeholders involved in each project, following the division made by Roos et al. (2010). Included in the group of the stakeholders are the industry which supplied the timber for the structure of the buildings. The goal of this chapter is to highlight whether or not the similarities identified in Chapter 5 are somehow connected with the stakeholders of the projects, or to connected R&D researches. Knowing or understating the motivations, the influences and the clients involved helps to shed light on the context in which the MTBs were designed and built. The second part of the analysis will shed light on the professionals who were involved, how often and in how many other MTBs they were involved. It will be possible to understand who influenced the design of the MTBs by the identification of pattern of interdependence and repetitions of s takeholders. In some cases it was a design characteristic proper of the architect, other times of the engineer, other times of the timber suppliers. This analysis will explain the cluster of similarities observed in Chapter 5, and identify common R&D-based projects.

6.1 Literature on the Contextual Analysis of MTBs

The literature on the context and drivers of MTBs is generally country-based and with few studies included in their comparison or research from more than one country. Here, the literature analysis is divided in two sections: one dedicated to the more traditional studies on the context such as regulatory framework, and another section is dedicated to the stakeholders' analysis.

6.1.1 Literature on the Regulatory Framework and Barriers

The regulatory aspects and their influence on MTBs were studied in a large body of the literature (Lattke and Lehmann, 2007) (Tykkä et al., 2010) (Nord et al., 2011) Östman and Källsner (2011) (van Egmond, 2011) (Riala and Ilola, 2014) (Toppinen et al., 2019) (Lazarevic et al., 2020). These studies observed that in many European countries, more relaxed and timber-friendly regulations (especially on fire regulations) allowed developers to build M TBs. Also in North America, building regulations were the main barrier for many years in the realisation of MTBs (Wiegand, 2019).

Mahapatra and Gustavsson (2009) analysed the market penetration of MTBs in several European countries, observing the factors which may have influenced their final de sign. The report evidenced the presence of different regulations which limit (or allow) different heights. The report evidenced that fire s trategy w as t he m ain r eason o f i nfluence. Fu rthermore, it al so an alyses th e timber industry market and its potential in these countries, together with the different ways to promote MTBs. Only Sweden emerged as advanced-stage market context for the realisation of MTBs according to the authors. These considerations were confirmed in another similar study (Mahapatra et al., 2012).

Nord et al., 2011 analysed the industrial and MTBs' market in several European countries and arrived at some recommendations to policymakers after having pointed out innovative countries

examples such as Austria and Sweden. Similar recommendations are made by Clark et al. (2012). His study evidences that the R&D activities are playing a relevant role in the establishment of tall timber buildings, but they are not enough. The authors suggest that R&D should be focused on process, organisational and market innovation instead.

Gosselin et al. (2015) studied some Canadian timber projects, analysing the barriers and motivations for the use of timber in residential and non-residential case-studies. The outcome of the study, both sustainability and technical aspects, were the main reasons why the selected case-studies were built (see Figure 6.1). On the other hand, the same study identifies the presence of barriers like building regulations or lack of expertise that block more MTBs in the country.

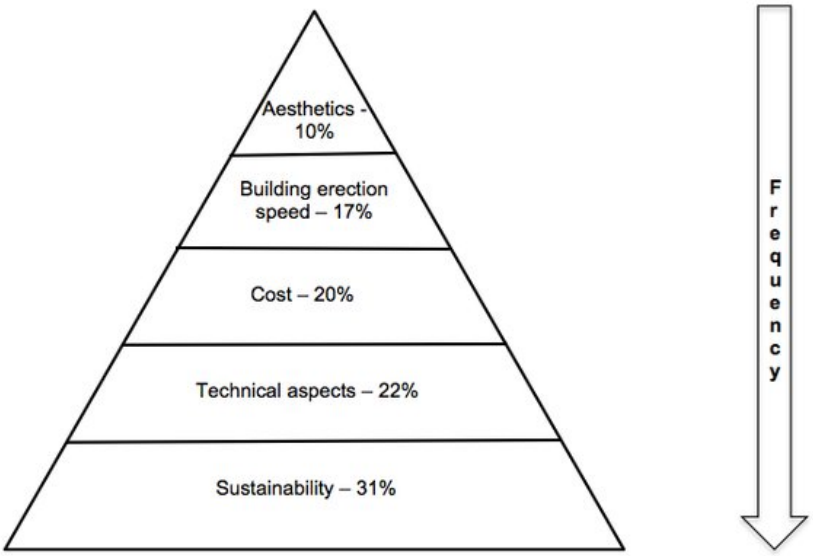

Figure 6.1: Weighted motivations for the adoption of timber as a structural material for non-residential buildings

Source: (Gosselin et al., 2015)

One of the most specific study on the topic was made by Hurmekoski et al. (2015). The goal of the study was to analyse the market potential of wood-frame multi-story construction (WMC), after the observation that some countries had more projects completed than others. The conclusion of the study led the authors to say that the diffusion of these buildings is dependent on regulatory framework and the structure of the construction industry. These are the drivers which influenced the existing MTBs and will lead to future MTBs. The study also divide the European market into several macro-regions, namely: Northern Europe [1], Central Europe and the UK [2], Western Europe[3] and Southern and Eastern Europe[4]. These macro-region have different intensity ordered (regarding the potential of market penetration by 2030). The Scandinavia area is reported as highly potential, whereas the Southern and Eastern Region of Europe have the lowest potential.

[1]Finland, Norway, Sweden
[2]Austria, Northern Italy, Southern Germany, Switzerland, the UK
[3]France, Ireland, the Netherlands, Northern Germany
[4]The Czech Republic, Hungary, Poland, Southern Italy, Spain

Bowyer et al. (2016) and Goodland (2016) observed the trend since the 1990 of some governmental initiatives to favour the construction of MTBs thanks to low-carbon emissions requirements, and in some cases, to actively request the construction of MTBs. Goodland (2016) in particular made a world study on the topic and found that different policies were implemented to promote timber, also in MTBs. The majority and the most significant were in North America and Europe. Thanks to these policies and initiatives, the number of tall buildings is increasing. Goodland (2016) also observed that the most effective policy relies on Life Cycle Assessment (LCA) which establishes the optimal material to be used for its life-cycle, in which timber is highly advantaged.

Wiegand (2019) observed in his study that the literature on the drivers of Tall Wood Buildings (TWBs) *"establish the relevance of the support of governmental policies on TWBs"*. The author then structures his thesis on the analysis of how these policies have actually impacted the development of tall wood buildings (TWBs). The conclusion of this work is the observation that the policy instruments (as R&D or regulatory instruments) were effective tools in the realisation of MTBs. The study highlights repetitions of influences of R&D or of public programs. The author suggests that *"(...) it may be valuable to do more research on the new relationships or alliances which have resulted from the collaboration between professionals, academics and companies involved in TWBs."* (Wiegand, 2019).

6.1.2 Literature on Stakeholders

The literature on the stakeholders involved, and their influence as drivers in the realisation of MTBs is scarce. Some early studies mentioned the stakeholders involved in the case-studies analysed, but without any particular comments (Falk, 2005) (Lattke and Lehmann, 2007) (Lehmann, 2012). From these studies it was possible to observe some repetitions by the architects, engineers or developers. Holt and Wardle (2014) included in their survey, qualitative information provided by some of the stakeholders involved, and Smith et al. (2015) included in the data analysis the architects, the timber suppliers and the contractors of the case-studies. Salvadori (2017) listed the main stakeholders (architects, engineers and timber suppliers), and summed up the most repetitive architectural offices.

Some books mentioned the stakeholders involved in the selected case-studies, and in some cases they provided wider contextual information regarding the country in which the case-study was realised (Green and Taggart, 2017) (Kaufmann et al., 2018). Mayo (2015) provides the timber market context of the countries, and the policies which were involved in the selected case-studies. Additionally, stakeholders information is given by websites and online databases, but specific analysis are not carried out by these data sources.

Roos et al. (2010) focused on the attitudes of architects and engineers toward timber in multi-storey construction. In doing so, the authors defines the major stakeholders who take part in the realisation of MTBs. These are architects, structural engineers, timber suppliers, contractors, developers, authorities, and end-users. Throughout a series of interviews and focus-groups, the

author displayed the attitude toward timber of the stakeholders (see Figure 6.2). For example, it emerged that architects and engineers *"(...) sensed that most of the influence over material selection rested with developers and contractors."* (Roos et al., 2010).

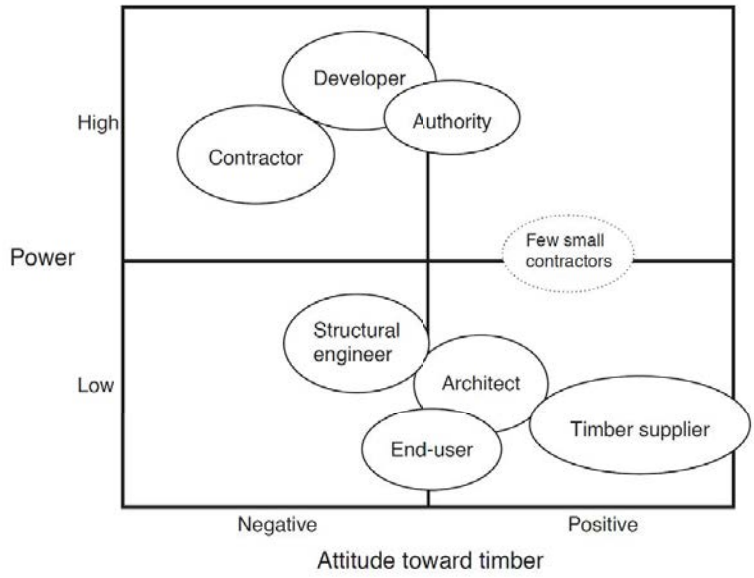

Figure 6.2: Stakeholder power and attitude in the process of material selection

Source: (Roos et al., 2010)

Tykkä et al. (2010) identified timber framed innovators in some European countries. The analysis of their sources of innovations pointed out that they became active actors in the construction industry. They received governmental support for both R&D and knowledge transfer, but they also learned from their experiences, and both made them active actors.

6.1.3 Lessons Learned from the Literature Review

What emerges from the analysis of the previous academic research on the contextual influences of MTBs is that the policies made by the governments in Europe and North America are the main drivers to promote the realisation of MTBs. Additionally, some studies convey an important role to the structure of the local timber industry. Policies and R&D developments prepare the necessary foundation to then realise the projects. However, Wiegand (2019) suggests that, even if polices have to be considered the main drivers, the relationships between these polices and the network of the professionals involved in the case-studies should be further analysed. This and other hints are listed below and are collected as the main points which emerge from the analysis of the literature:

1. **Regulatory framework:** from the analysis of the literature, it is clear that the regulatory framework and policies affected the design and the realisation of MTBs. Since this topic has been widely researched, this study will still consider the policy involved, but it will focus on the other related aspects less considered by the literature, in order to enrich the academic discourse.

2. **Type of commission:** no study compared the origin of MTBs. The literature shows the influence of governmental economic support, or the facilitation by public players in the know-how transfer. No real comparative analysis was carried out to understand how many projects were realised thank to public or private initiative and influence. Furthermore, no analysis ever displayed the type of commission with which MTBs were designed. Are they the result of a direct commission, or are they selected after an architectural competition? In this regard, it would be also interesting to analyse whether or not the architectural competitions favour the international exchange of know-how, or if they were won by local teams.

3. **Motivations:** if the topic of barriers is sometimes discussed by the literature, only few studies analysed the motivations behind the realisation of MTBs. Sustainability is recognised by Gosselin et al. (2015) as the most influential reason in a selected number of Canadian case-studies. In this regard, a more comprehensive analysis will confirm, discard or enrich the literature. Additionally, the analysis of public, private, or both would clarify if MTBs are a mainly public-founded phenomenon, or if the private initiative represented a relevant influence.

4. **Stakeholders analysis:** several studies mentioned or reported the main players involved in the design and construction of MTBs, but none studied or researched the relationships and patterns of interdependence between case-studies and stakeholders, neither the frequency of the involved stakeholders. The analysis of the professionals involved will shed light if the repetitions observed in Chapter 5 are somehow related to them. Furthermore, a limited number of stakeholders involved suggests a niche professional context, which was observed by some previous studies, and was considered unfavourable for the growth of the MTB market.

5. **Timber supply:** besides (Smith et al., 2015), no other study ever compared the companies who supplied the necessary EWPs to the built case-studies. Therefore, the literature does not confirm if MTBs always use local EWPs, or if the buildings were supplied by timber manufacturers from other nations or continents.

Based on these comments, the hypothesis of this dissertation is that there are other affecting elements in the realisation and the design of MTBs. For this reason, the regulatory framework and the different policies involved in each case-studies will be mentioned, but they are not the main focus of this work. The analysis of the literature indicated some "blind spots" which need to be further investigated and compared. These topics are: the network of the stakeholders involved, the type of commission, the influences and motivations, and from where the necessary EWPs were supplied. The next section will describe the survey methodologies adopted, with the categories of analysis selected to answer the research question why were MTBs built and who built them?

6.2 Survey Methodology of the Contextual Analysis

In light of the findings and lessons learned from the existing literature, the following section describes which categories of analysis were applied to the case-studies and later compared. Categorising the influencing factors is a complex task, considering there are many influences. In this dissertation emphasis is given to the type of client and commission of these projects and to the stakeholders involved. When necessary or important, building code changes, R&D programs, joint-venture projects, and policies were also mentioned in order to give a better contextual situation in which the case-studies were involved.

The next section defines the different categories of analysis chosen to answer the research question why were MTBs built and who built them? The categories are divided between two groups: influential factors and stakeholders. In some case-studies, data was not available and was indicated with "n/a" (not applicable). This chapter continues with the analysis of the projects in each country, as done in Chapter 5. When possible, the projects were described in order by their "influence", meaning projects that influenced another project were listed first. Data sources are described in Section 1.3.2. For this specific chapter, the correspondence with some of the stakeholders involved was widely used, since the data on the motivations was not always available in the literature and online. Often times, the answers could not be triangulated with others, and the author acknowledges a possible limitation of this survey. Besides the qualitative description of the projects according to their context, every country has a list of the stakeholders involved in the case-studies, along with a graph which presents the relationship between the case-studies and the stakeholders involved. This helps to graphically show the direct influences between the projects analysed.

The outcome of the country analysis will show that some of the similarities found in Chapter 5, are mostly dependent on stakeholders' "know-how". In the final section of this chapter, the data gathered separately in each country are compared from a global perspective. The analysis will identify the private and public ratio of commission in each country, the type of this commission, what were the main reasons, and how often the stakeholders were found to be repetitive in the selected case-studies. These final analyses show that MTBs, especially for timber engineering and manufacturing are a niche practice.

6.2.1 Influential Factors

A first layer of analysis was the qualitative analysis of the type of the commission which the case-studies had and who were the developers or clients. Were they public or private clients? Was the government or a public university involved? Was the project commissioned directly or after an architectural competition? These were the main questions which this analysis wanted to answer, and in order to do so, the type of client, and the type of the commission were described according to several categories.

Clients and Influences

The first category of analysis regarding the context of the selected case-studies is the origin of their realisations. In this case, the type of client were divided between public and private. When a project was the result of positive interaction between both private and public players like joint ventures, public financing of projects, or R&D co-founded by public and private players, the case-study was considered to belong to a third category.

- **Public:** when a case-study was realised thanks to the main role played by a public player. Several types of public players were observed: they can be a city, a district council, a public university or a student association housing agency.
- **Private:** in the case in which the investor was a private player, the project was considered privately influenced. There were cases where the government was later involved in the decision process and modified the regulatory framework for the realisation of the project. Other times, the EWPs (or the structural concepts) used in the case-studies were the result of a partially publicly founded R&D program which was not strictly connected with that specific project. In both and other similar cases the main influence was still considered private.
- **Private-public:** were considered the case-studies in which a private investor financed a building, but at the same time, other public players were involved. These can be local government which set the competition rules for the design of MTBs, universities which provided relevant R&D support or collaboration, or student associations who commissioned private players to build directly MTBs.

Type of Commission

The literature does not identify how these projects were commissioned: was there a direct commission, or was the design awarded after an architectural competition? The implications are different. A competition should procure the best architectural design. It should also encourage fresh ideas, and assess a wide range of approaches to a design challenge, especially when it comes to timber. Alternatively, direct commissions can speed up the decision process and would rely on experienced professionals.

- **Architectural competition:** an architectural competition can be a tool which a client uses to increase the competition and the span of choices of a project. These types of competition can be organised by a public or private player. After the projects are submitted by the design teams, a jury awards the best design.
- **Direct:** a more traditional way is the direct commission of the project to a specific design team or architect. This choice has the advantage of shorting the time, and it can be carried out by both public and private investors.

Influential Factors on the Decision to Build an MTB

Thanks to existing literature, professional website, correspondence, and other sources mentioned in the data sources in the Introduction chapter (see Section 1.3.2), it was possible to understand the reasons behind the realisation of the selected case-studies. As previously acknowledged, this information was seldom available to triangulation. Based on the spectrum of possibilities, all the case-studies were categorised by the following main reasons:

- **Sustainability:** the goal of building a sustainable building was reported as the main motivation in many projects. The private or public investors which financed the building usually opted to qualify for energy or sustainability certification of the building as well. These are certifications like LEED, BREAM, CasaClima, BBCA, Minergie and others.
- **Technical aspects:** there were some case-studies which were considered by public or private client mainly for the reasons connected to the properties of timber in construction. These could have been mechanical or physical properties, insulation, low noise emissions and lightweight structure. The lightweight property of timber was one of the most frequent technical reasons for building a project with a timber structure. Both the case-studies which are additions to an existing building were built with timber because it allowed more to be built thanks to its lightweight. Similarly, several case-studies had to be built with timber due to soil's low bearing capacity.
- **Building erection speed:** in several case-studies the stakeholders reported timeliness of completion as the main motivation for pursuing a timber project. A fast construction time means, in most cases, a lower cost for the investor. Additionally, many student housing and educational case-studies were built with a timber structure due to a strict time schedule, using the window of time between the two semesters.

6.2.2 Stakeholders

A particular emphasis is given in this work on the network of stakeholders involved in each case-study. Here, "stakeholders" are considered all the professionals involved in the design and construction of the case-studies. Below are listed the typical professional divisions from Roos et al. (2010), with the specification between engineer and timber engineers. In this list the "Authority" and "End-users" groups are not considered.

- **Architects:** the professional figure who generally decides the design and architectural outcome of the building. In general, they could get the commission in different ways: privately by an investor, publicly by an institution, via architectural competition or by themselves.
- **Engineers and Timber engineers:** engineers are commissioned for the calculation of the structure of the project. In some case-studies a project can have both an engineer and timber engineer of record.

- **General contractors and Timber contractors:** the general contractor is the construction company who is responsible for the erection of the entire project. The general contractor company sometimes commissions other sub-contractors to realise other parts of the building. Sometimes the general contractor erected the timber structure, other times, it relied on timber contractors specialised in these type of structures. Timber contractors often purchase the EWPs from the timber manufactures and then erect the timber structure. Other times, the same company who manufactured the structural timber elements was also the company who then erected them. In some cases, under this category are reported the intermediary companies who were responsible for the import of the foreign timber elements. For some companies, it was not clear if they were also providing the erection of the elements.

- **Timber suppliers:** are the companies who provided the EWPs to the general contractor or the timber contractor. These companies produced the EWPs by processing the trunks which are not always from the same country of the industry. Besides supplying the project, the majority of the companies provide timber engineering services. Some companies like Martinsons can also erect the timber structures they supply.

- **Developers and Clients:** developers are construction companies specialising in the process of the construction. They usually manage large properties and combine construction expertise in real estate. Other times the project is built thanks to a wish of a client, who could be private or public (University, City, Association).

In the final section, a global comprehensive analysis is made of the stakeholders involved. When graphically compared, the countries are organised by most repetitive stakeholders. In some countries, some of them were involved in more than one case-study, and in some cases they were involved in many case-studies. In these graphs, the stakeholders are categorised by stakeholders involved in one case-study, in two case-studies, and more than three case-studies. By doing so, the analysis will compare the frequency of repetitive professionals in each country.

6.3 Contextual Analysis of the Case-Studies

The multiple-country study presented in this section has been performed to explore and compare how the 197 case-studies were affected by the context in which they were built. As for the design analysis in Chapter 5, the case-studies are divided into their own country-group. The countries are then organised by their Continent-group, and in alphabetical order. Most of the time the analysis of the context follows a relationship order between the case-studies. When there were no relevant connections between them, the analysis was carried out in a chronological or geographical order. Besides the qualitative description, each country has a table in which the stakeholders are listed. Additionally, in every country-section a graphical image represents the main relationships between stakeholders and case-studies.

6.3.1 Austria

see Appendix pages 305-320

Austria became the first country to implement a performance-based building code which favoured the use of EWPs (Meacham, 2009). Being a federal Republic, every region of Austria has different Building Code requirements. In Steiermark for example, three-storey timber buildings were already allowed in 1970. However, the Austrian government improved the framework conditions for MTBs with the national amendment to the Construction Technology Ordinance of 2017. With it, up to six storeys can be built with timber without a special permit. Before that, only four floors were possible without an additional report (Mayo, 2015).

After completing the four-storey project *Frauengasse I&II* in 2002, the architect Hubert Riess was involved in the first case-study of this survey, the five-storey building *Spöttlgasse*. *Spöttlgasse* was designed and built because in 2001, the Vienna Code allowed for the first time ever, five-storey buildings to be built with mixed timber materials as part of the structure, thanks to the introduction of the performance-based code (Meacham, 2009). The building code also obliged the building to be hybrid, with the mandatory requirement of the escape routes (cores) to be built of non-combustible material (Falk, 2005). All the stakeholders involved in this project will further appear in the analysis of the Austrian case-studies. The project was promoted by the Social Housing Company of Vienna. The capital of Austria has a long and powerful history with social housing projects and Vienna owns the majority of the flats of the city (Bauer, 2006). *Spöttlgasse* was the first of a series of real estate developments supported by the city in order to promote the local timber industry. Together with ProHolz, a governmental organisation which promotes the use of timber in Austria, other architectural competitions were carried out in order to promote timber as structural material. The engineering offices involved in *Spöttlgasse* were JR Consult and Woschitz Group. Richard Woschitz, the founder of Woschitz Group, worked at the beginning of his career at the Technical University of Vienna, in the department of Structures and Timber engineering. After obtaining a PhD on hybrid floor systems made of timber and concrete, he founded Woschitz Group in 1996. The hybrid approach which characterised his academic work, can be seen in all five case-studies where Woschitz Group was involved. The Austrian KLH supplied the CLT, which at that time (2004) was one of the few CLT suppliers in the world (Fourthdoor, n.d.*b*). This project is the first case-study in which Kulmer Holzleimbau was involved. The Austrian timber contractor is also involved in other Austrian case-studies.

After *Spöttlgasse*, an architectural competition was organised by the city of Vienna for the *Mühlweg* urban development. The project was supported by the city, with the prerequisite that the competition must be focused on designing an innovative project with timber. Three architectural offices won the competitions and built three different projects. Dietrich Untertrifaller Architekten (DUA) designed *Wohnsiedlung Mühlweg Bauteil C* which has five storeys (Untertrifaller, 2010), meanwhile the others are all four-storey buildings and were designed by architects Hubert Riess and Hermann Kaufmann Architekten (Kaufmann et al., 2018). All the buildings are hybrid panelised timber-concrete. DUA, like architects H. Riess and H. Kaufmann, had considerable experience

with timber construction and similarly to H. Kaufmann, DUA has its headquarter in the Austrian region Vorlaberg, famous for its historical and modern timber buildings (Dangel, 2009). In all the projects, KLH provided the CLT walls and floors elements.

Two other projects on the list benefited from the initiative of the city of Vienna. Thanks to the program called "Holzbau in der Stadt" (timber in the city) *Wagramerstrasse* and *Gesundheits.Quartiers* were completed in 2013 and 2019 respectively (Schluder, 2012) (Wiegand, 2019). Both of the projects have Woschitz Group as their engineer of record, and both share the same structural system: concrete core, panelised structure with hybrid concrete CLT floor slabs. The architect of *Gesundheits.Quartiers* project is the same of the Viennese case-study *Gleis 21*, completed in 2019. While the *Gesundheits.Quartiers* were built thanks to influence of the city, *Gleis 21* was the result of the wish of the so-called "Baugruppe" (co-housing), private citizens which gather together with assistance from the city, and obtain a plot ("Gleis" in German) where they can build their building. In this case the buildings have similar structural and architectural characteristics. In both the projects, the company XC supplied the hybrid timber-concrete floor slabs. XC is a company born from a joint venture between the Meyr-Melnhof and Kirchdorfer Group (Holzbetonverbund, n.d.). The company supplies timber-concrete floor slabs which have already been pre-assembled. Besides these two projects, the same company also supplied the two *HoHo* projects.

Eight other case-studies were the result of private initiatives. The case-study *BMW-Hotel Alpenhof* was the result of a competition launched by the BMW group (the German auto producer) which wanted an innovative hotel for its employees. Oskar Leo Kaufmann and Albert Rüf won the competition together with the engineering office Merz Kley Partners (which had years of experience with timber structures) and the timber contractor Kaufmann Bausysteme, a company out of Vorarlberg which is specialized in 3D prefabricated modules. However, Kaufmann Bausysteme does not produce timber, so this project was supplied by the CLT producer KLH. The winning proposal of the design team was based on a previous 3D structural system developed by the architects together with Kaufmann Bausysteme called System 3 (Mayo, 2015). This system was adopted to the competition and building requirements. The proposal involved building 3D modular hotel-rooms, produced by Kaufmann Bausysteme in its warehouse and then transported in the building site ready to be mounted. The first two floors of the building were built with concrete due to the high snow level in winter season (Mayo, 2015). Fire regulations also imposed concrete cores and the team had to prove the feasibility of the fire strategy (Mayo, 2015).

The company Kaufmann Bausysteme was also involved in three other Austrian (and one German) case-studies: *Seniorenwohnheim*, *Hummelkaserne*, *Reininghaus Sud* and the German case-study *Woodie*. The project *Seniorenwohnheim* is a retirement home which needed to be rebuilt, so the owner launched a competition. For the construction period, the residents had to be accommodated in a temporary location and therefore the project needed a rapid construction time and low noise pollution on site. These criteria created the basis for Kaufmann Systeme's winning design which delivered a 3D CLT modular system quickly (proHolz, n.d.). The modular system was supplied

by Mayr-Melnhof. The engineer of record was Merz Klay Partners, meanwhile the architect and the timber producer involved in the realisation of *Seniorenwohnheim* were also involved in the *Hummelkaserne* project located in the city of Graz, with Merz Klay as engineer of record. However, the two buildings do not have the same structural system. *Seniorenwohnheim* was built with 3D modules, while *Hummelkaserne* was built with 2D highly prefabricated elements. The reason lies in the fact that the *Hummelkaserne* project was then outsourced to Kulmer Holzleimbau (which was involved in other 2D CLT panelised projects like *Reininghaus Sud*) as a subcontractor for reasons of capacity: this is the reason for it then being carried out in panel construction (Reichelt, 2020).

Life Cycle Tower (or LCT) and *Illwerke Zentrum Montafon* share the same core team of architects, engineers and general contractor. In the case of LCT, the client was the same general contractor, whereas for the *Illwerke* project, the client was another private company. The two projects share the same structural system and CREE patented the pre-assembled systems (Green and Taggart, 2017) (Kaufmann et al., 2018). The story of these projects starts with the collaborative research called "8+", which was supported by the Austrian national R&D program "Haus der Zukunft". The program involved both academics and professionals (Mayo, 2015). This collaboration generated the concept called "Life Cycle Tower One". *Life Cycle Tower* plan is a quarter of "Life Cycle Tower One" and uses the system created by high prefabrication and hybridisation of the timber-concrete components (Zangerl et al., 2010.). The same core team was then involved in the architectural competition for the new headquarters of the company Illwerke Montafon and won it. Prefabrication of the structural elements, of the floors and of the facade are also characteristics of this project. Timber is visible because a sprinkler system compensates for the flammability of the building material (proHolz, 2020*a*). Connected to the "Life Cycle Tower One" is the German case-study *H7*. *H7* was engineered by the company Arup which was involved in the "Life Cycle Tower One" program (Hein et al., 2016).

The *Reininghaus Sud*, *Holzwohnbau Rosenstraße*, *Mineroom*, and *Holzwohnbauten im Dragoner-Quartier* are all projects built in other cities besides Vienna. The players are not recurrent in the analysis, except for in the case of the timber contractor company Weissenseer, which was the general contractor of *Gleis 21*. All timber manufacturers for these projects are Austrian. The *Reininghaus Sud* competition was won by the architectural office Nussmüller Architekten, which proposed timber as a structure (proHolz, 2020*b*). The office had previous experience with mass timber projects. The project is part of the "House of the Future" and "Energy City Graz-Reininghaus" public programs, therefore the competition required a sustainable design with passive standards (proHolz, 2020*b*). The company which built the timber parts was Kulmer Holzbau, the same company which was involved in the first CLT projects *Spöttlgasse*, *Wohnsiedlung Mühlweg Bauteil C* and *Hummelkaserne*. The staircases are made of reinforced concrete for fire protection, and are used to derive the horizontal forces. Similarly, the walls were planked with gypsum boards for fire safety. Only the ceiling was allowed to be visible.

Built in the middle of Linz *Holzwohnbau Rosenstraße* was the desire of the Linz diocese which

commissioned X Architects to pursue the design of the publicly funded building (Gruber, 2015). In fact, the location created several logistic challenges, with its narrow streets. A previous building was demolished, and the resulting gap was filled with a timber building. KLH provided the CLT panels. The project was designed in strict contact with the authorities.

The realisation of *Mineroom* was preceded by a competition organized by Wohn- und Siedlungsgenossenschaft Ennstal with the requirement of offering the project as a complete service with a general contractor (Nextroom, 2017*b*). The reasons for this were primarily the high time pressure and the price guarantee associated with the general contractor model. The competition was won by aap.architekten together with the timber construction entrepreneur Weissenseer and the Swietelsky Baugesellschaft, who received the general contractor order by proposing timber as solution for the time schedule. Weissenseer is specialised in pre-assembling and for *Mineroom* used CLT from KLH.

Holzwohnbauten im Dragoner-Quartier was a pilot project sponsored by the city of Wels and carried out by a private investor which revitalised an abandoned area. However, the design of the building had to follow strict fire requirements which limited the timber exposure inside the residential units (Hagleitner, 2017).

The tallest hybrid timber structure in the world by the end of 2019 was initiated by a private company. *HoHo Next* and *HoHo Wien* are part of the same development, but have been completed in different years. Both the buildings are the result of the private initiative led by Cetus Baudevelopment. The investor commissioned Rudiger Leiner Architekten to build the project involving Woschitz Group as the timber engineer. The team needed special permission to build the twenty-four-storey tower, and needed to do several tests on elements like the floor system for the authorities (Woschitz, 2019) (Vihemäki et al., 2019). The structural system of the two buildings is the same and so it is the fire concept (Woschitz, 2019).

Hermann Kaufmann Architekten, SPS Architekten, einszueins architektur and Rudiger Leiner have all two case-studies built. Offices like Dietrich Untertrifaller Architekten or Hubert Reiss (each having one built case-study) were involved in other relevant timber projects. Regarding the engineer offices of record, as previously mentioned, Merz Klay and Woschitz Group were involved as timber engineers, together, in more than half of the case-studies (5 and 4 respectively). Kaufmann Buasysteme is the most frequent timber contractor with three case-studies built. Nearly all the timber manufacturers for these case-studies are Austrian, with the Swedish-Finnish company Stora Enso involved in two case-studies[5]. In the Austrian case-studies, both public and private actors have a relevant role in the support of timber as structural material. Sustainability goals were the main motivations for the construction of Austrian projects.

[5]By the end of 2019, the company Stora Enso produced all its CLT in Austria (Jauk, 2017).

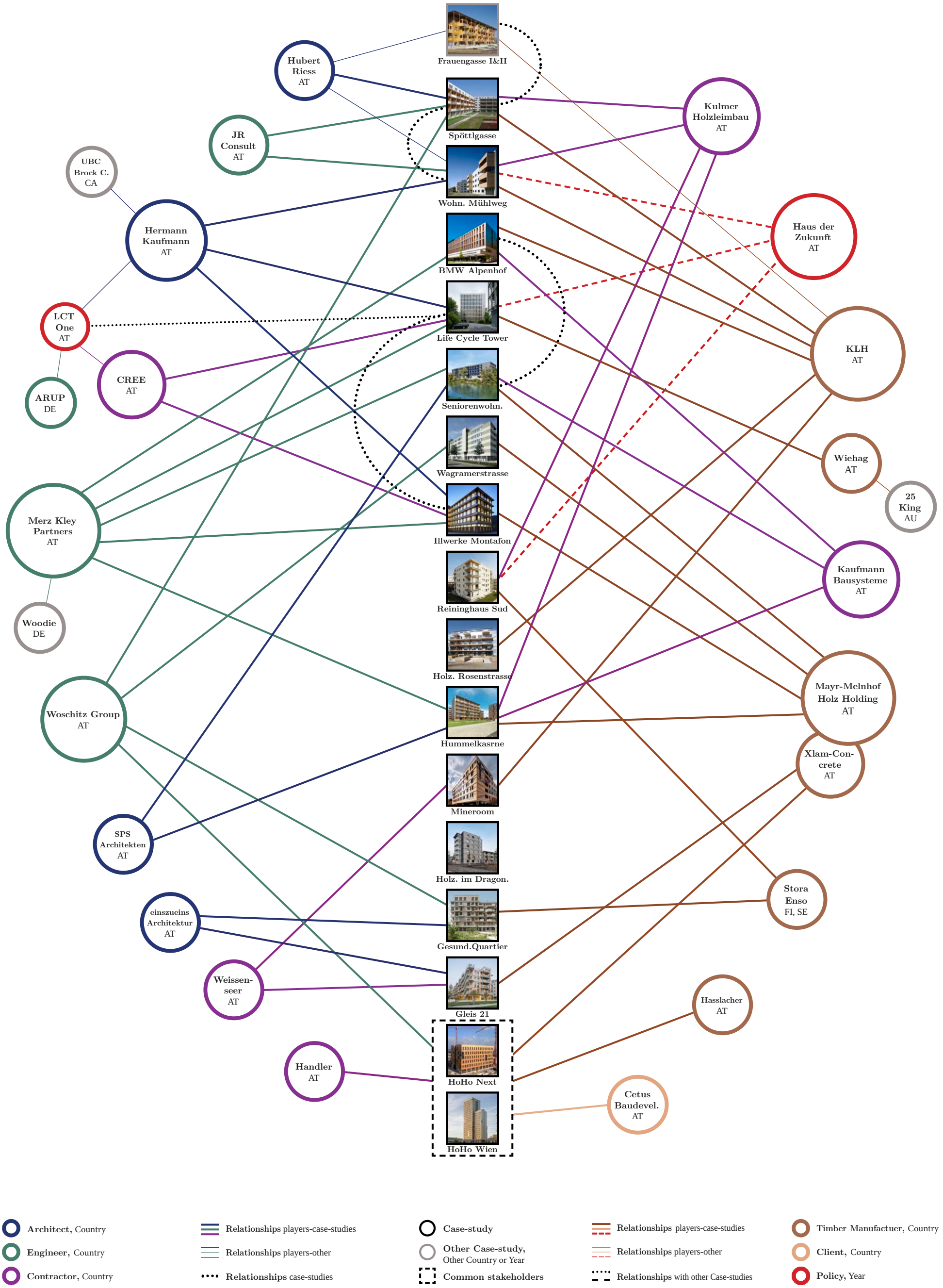

Figure 6.3: Relationships between Austrian case-studies, policies and their stakeholders

Table 6.1: List of stakeholders involved in Austrian case-studies

Project *(name)*	**Architect** *(name, country)*	**Engineer** *(name, country)*	**Timber Engineer** *(name, country)*	**General Contractor** *(name, country)*	**Timber Contractor** *(name, country)*	**Timber Supplier - Structural elements** *(name, country)*	**Timber Supplier - Floor slabs** *(name, country)*	**Client/Developer** *(name, country)*
Spöttlgasse	Hubert Riess, AT	JR Consult , AT	Woschitz Group, AT	Kulmer Holzleimbau, AT	Kulmer Holzleimbau, AT	KLH, AT	KLH, AT	Sozialbau AG, AT
Mühlweg Bauteil C	Dietrich Untertrifaller Architekten, AT	JR Consult , AT	KLH, AT	Kulmer Holzleimbau, AT	Kulmer Holzleimbau, AT	KLH, AT	KLH, AT	BAI Bauträger Austria Immobilien, AT
BMW-Hotel Alpenhof	Oskar Leo Kaufmann - Albert Rüf, AT	Mader & Flatz, AT	Merz Kley Partners, AT	Kaufmann Bausysteme, AT	Kaufmann Bausysteme, AT	KLH, AT	KLH, AT	BMW Group, DE
Life Cycle Tower	Hermann Kaufmann Architekten, AT	Merz Kley Partners, AT	Merz Kley Partners, AT	CREE Rhomberg, AT	Sohm Holzabutechnick, AT	Wiehag, AT	Wiehag, AT	CREE Rhomberg, AT
Seniorenwohnheim Hallein	SPS Architekten, AT	Merz Kley Partners, AT	Kaufmann Bausysteme, AT	Kaufmann Bausysteme, AT	Kaufmann Bausysteme, AT	Mayr-Melnhof Holz, AT	Mayr-Melnhof Holz, AT	Stadtgemeinde Hallein, AT
Wagramerstrasse	Schluder Hagmüller Architekten, AT	Woschitz Group, AT	Woschitz Group, AT	Voitl & Co, AT	Aichinger Hoch-, Tief-, Holzbau, AT	Binderholz, AT	Binderholz, AT	Familie Gemeinnützige, AT
Illwerke Zentrum Montafon	Hermann Kaufmann Architekten, AT	Merz Kley Partners, AT	Merz Kley Partners, AT	CREE Rhomberg, AT	CREE Rhomberg, AT	Mayr-Melnhof Holz, AT	Mayr-Melnhof Holz, AT	Vorarlberger Illwerke, AT
Reininghaus Sud	Nussmüller Architekten, AT	Kulm Bau, AT	Kulm Bau, AT	Kulmer Holzleimbau, AT	Kulmer Holzleimbau, AT	Stora Enso, FI, SE	Stora Enso, FI, SE	Aktiv Klimahaus WeGraz, AT
Holzwohnbau Rosenstraße	X Architekten, AT	TRIAX, AT	Brüder Resch, AT	Brüder Resch, AT	Brüder Resch, AT	KLH, AT	KLH, AT	Diözesane Immobilien-Stiftung, AT
Hummelkaserne	SPS Architekten, AT	Merz Kley Partners, AT	Merz Kley Partners, AT	Kaufmann Bausysteme, AT	Kulmer Holzleimbau, AT	Mayr-Melnhof Holz, AT	Mayr-Melnhof Holz, AT	ENW – Gemeinnützige Wohnungsgesellschaft, AT
Mineroom	aap.architekten, AT	Kurt Pock, AT	n/a	Swietelsky, AT	Weissenseer Holz-System-Bau, AT	KLH, AT	KLH, AT	Wohn und Siedlungs-genossenschaft Ennstal, AT
Holzwohnbauten im Dragoner-Quartier	Luger und Maul, AT	Obermayr Holzkonstruktionen, AT	Obermayr Holzkonstruktionen, AT	Obermayr Holzkonstruktionen, AT	Obermayr Holzkonstruktionen, AT	n/a	n/a	WAG Wohnungs-anlagen, AT
Hoho Next	Rudiger Leiner Architekten, AT	Woschitz Group, AT	Woschitz Group, AT	Handler, AT	Handler, AT	Hasslacher Norica Timber, AT	XlamConcrete, AT	Cetus Baudevelopment, AT
Gesundheits.Quartiers	einszueins architektur, AT	Woschitz Group, AT	Woschitz Group, AT	Strobl Bau-Holzbau, AT	Strobl Bau-Holzbau, AT	Stora Enso, FI, SE	Stora Enso, FI, SE	At home Immobilien, AT
Gleis 21	einszueins architektur, AT	GG Ingeniueure, AT	GG Ingeniueure, AT	Schwarzatal, AT	Weissenseer Holz-System-Bau, AT	Mayr-Melnhof Holz, AT	XlamConcrete, AT	Baugruppe Gleis 21, AT
Hoho Wien	Rudiger Leiner Architekten, AT	Woschitz Group, AT	Woschitz Group, AT	Handler, AT	Handler, AT	Hasslacher Norica Timber, AT	XlamConcrete, AT	Cetus Baudevelopment, AT

6.3.2 Benelux

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Scarce public involvement was reported in the promotion of timber in Belgium and in the Netherlands (Oliver and Venables, 2012). Some initiatives are carried out by Centrum Hout (Netherlands), which promotes timber, but is the only main voice Oliver and Venables (2012). No public policy with the goal of promoting timber was found in Belgium (Oliver and Venables, 2012).

The two Belgian projects have in common the engineering office (Ney & Partners) and the same CLT manufacturer (Laminated Timber Solutions) which produces CLT in Belgium (Ney&Partners, 2020). Both the investors are private real estate developers. The reasons of using timber were different: if for *Les Closières* the developer decided to use of CLT due to sustainability targets, in the case of *Kietude* the properties of timber played a decisive role (Ernest, 2018). *Kietude* is located in a narrow street of the urban centre: this made difficult logistic operations and a traditional building site would have been too noisy. The team therefore considered alternative ways to build the project and CLT was chosen for quick assembly time and ease of transport (Ernest, 2018). Steel beams were chosen by the engineering office to support the sculptured facade designed by the architects.

The idea of building *Malmo Hus* was initiated by Tigchelaar architects. After an inspiring visit in 2001 to the international housing exhibition Bo01 in Malmö (Sweden), the architectural office came in contact with Swedish timber-construction methods and developed a concept that was panelised all-timber for the Netherlands (van Egmond, 2011). De Alliantie agreed to develop the project proposed by the architects, and the municipality of Almere was involved in researching for the appropriate location (van Egmond, 2011). Because the design is based on the Scandinavia construction method, *Malmo Hus* utilises LVL box-floor element typical of the Nordic countries. These floors were supplied by the Finnish company Metsä Wood. The German company Züblin Timber (at the time called Finnforest Merk) supplied the CLT panels (called "Leno Panels").

The initiators of *Patch 22* were the architects Frantzen et al. architecten. Together with building-manager Claus Oussoren, the team wanted to push the boundaries of timber construction and purpose an innovative building with flexible plans. They also decided to develop the project on their own and innovative financing solutions were conceived, being the project designed in the middle of the economic crisis (2009-2014) (Thematic Design, n.d.). Because of the location chosen by the developers, *Patch 22* needed insulating noise facade. The project is located in the edge of an industrial area and noise protection was necessary for the loggias. The chosen fire strategy was to oversize the timber structural elements in order to withstand the REI120 requirement imposed by the regulatory framework and therefore allowed the structure to be visible inside the flats (Thematic Design, n.d.). The structural timber elements were supplied both by Mayr-Melnhof Holz and by Laminated Timber Solutions.

Hotel Jakarta is the winning project of an architectural competition organised by the city of Amsterdam to design an hotel in a strategic and visible point of the city. Additional requirements

set by the Council, were the high sustainability standards which ended up favouring the use of timber (Koller, 2018). The competition was won by the team composed by the architectural office SeArch and the private hotel owner WestCord Hotels. During the competition phase, SeArch came up with the hybrid timber-concrete structure in coordination with the engineering office Pieters Bouwtechniek, which was also involved in the engineering of *Patch 22* (Koller, 2018). The Dutch company Ursem modulaire bouwsystemen built the 3D modules using the CLT panels supplied by the German manufacturer Derrix. Ursem modulaire bouwsystemen is a company specialised in assembling 3D modules made of different materials, and not strictly of timber, like for example Kaufmann Bausysteme.

Figure 6.4 shows the repetitive stakeholders observed in the case-studies. Both the two Belgian and Dutch case-studies shares the same engineering office, and the timber supplier of the Belgian case-studies supplied also some EWPs for *Patch 22*.

Figure 6.4: Relationships between Benelux case-studies, policies and their stakeholders

Table 6.2: List of stakeholders involved in Benelux case-studies

Project *(name)*	**Architect** *(name, country)*	**Engineer** *(name, country)*	**Timber Engineer** *(name, country)*	**General Contractor** *(name, country)*	**Timber Contractor** *(name, country)*	**Timber Supplier - Structural elements** *(name, country)*	**Timber Supplier - Floor slabs** *(name, country)*	**Client/Developer** *(name, country)*
Malmo Hus	Tigchelaar architects, NL	Lochem - Lüning Adviesburo, NL	Ingenieursburo Bartels, NL	Bouwbedrijf Kingma Bouw, NL	n/a	Züblin Timber, DE	Metsä Wood , FI	de Alliantie Ontwikkeling, NL
Les Closières	Banneton-Garrino Architects, BE	Ney & Partners, BE	Ney & Partners, BE	La Sambrienne, BE	Laminated Timber Solutions, BE	Laminated Timber Solutions, BE	Laminated Timber Solutions, BE	Le Val d'Heure, BE
Patch 22	Frantzen et al architecten, NL	Pieters Bouwtechniek, NL	n/a	Hillen & Roosen, NL	Korlam Nederland, NL	Mayr-Melnhof Holz, AT	Laminated Timber Solutions, BE	Lemniskade, NL
Kietude	Specimen Architects, BE	Ney & Partners - WOW, BE	Ney & Partners - WOW, BE	Invest Immo Belgium, BE	Laminated Timber Solutions, BE	Laminated Timber Solutions, BE	Laminated Timber Solutions, BE	Invest Immo Belgium, BE
Hotel Jakarta	SeArch, NL	Pieters Bouwtechniek, NL	Holzleimbau Derix, DE	Bouwbedrijf M. J. de Nijs & Zonen Warmenhuizen, NL	Ursem modulaire bouwsystemen, NL	Holzleimbau Derix, DE	Holzleimbau Derix, DE	WestCord Hotels, NL

6.3.3 Finland

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Two main players emerge from the analysis of the Finnish case-studies. One is the public/private real-estate developer Lakea Oy, which is Finland's largest developer of apartment buildings. Lakea Oy is a private company but is actually owned by 15 Finnish cities. The other is the Swedish-Finnish timber manufacturer Stora Enso. The company developed a 3D modular system which was applied to the majority of the Finnish projects.

The key year in for the realisation of MTBs in Finland was 2011 (Tolppanen et al., 2013) (Anttonen, 2015) (OOPEAA, 2020). During that year, new regulations for the use of timber in multi-storey buildings were executed, and they triggered a wave of new MTBs in the country (Hurmekoski et al., 2015) (Toppinen et al., 2019). Previously, several other program and policies promoted timber in the country. Some of these were the Nordic Wood program (1993-2002), MSO program and Runko PES, which all had the goal of improve competitiveness and industrial standardisation (Anttonen, 2015). These program also made possible to realise before 2004 some early MTBs in Finland and created a sharing knowledge panelised on timber construction (Anttonen, 2015).

The majority of the Finnish case-studies were influenced by a public player (or a public players were involved). The four case-studies *Puumera*, *Lintuviita*, *Puukuokka*, and *Mäihä* were all built thanks to a public-private joint venture, mainly involving a public client (a muncipality or Lakea Oy), Stora Enso (or another timber supplier) and a general contractor. The decision to build *Puumera* was made with a cooperation between the developer, the timber suppliers (Versowood Oy and Koskisen Oy) which were also involved as builders, and the city of Heinola (Projektiuutiset, 2011). *Puumera* is the only project in Finland with a concrete core and hybrid timber-concrete floor due to the fact that the construction started before the new fire regulations (which became more relaxed) were implemented (Projektiuutiset, 2011).

One year later, *Lintuviita* was completed and was built according to the new regulatory framework. The project is the result of a joint collaboration between the developer Lakea Oy and Stora Enso. It was the first project which was based on Stora Enso's "Urban MultiStorey" concept which consists of CLT modular elements pre-assembled in Finland, built from start to finish indoors and not exposed to weather conditions (Mikkola, 2014). Also *Puukuokka* (completed in 2014) and *Mäihä* (completed in 2016) were based on the same concept and in both the project the Department of Architecture at Tampere University of Technology has been involved, especially for the timber construction parts (Puuinfo, 2020*b*). *Puukuokka* was developed as a pilot project to test the "Urban MultiStorey" (OOPEAA, 2020). Additionally, *Mäihä* was the first PEFC-certified timber-residential building in the Nordic countries, certifying the commitment of the investors to have a highly sustainable building (PEFC, 2016).

In four case-studies a public client (municipality) favoured the design of timber. In two projects, was set a competition with the goal of building sustainable projects made of timber. In 2015, the City of Helsinki throughout its housing office ATT, organised an architectural competition

for *Eskolantie*. The competition specifically required the team to propose a timber building and once selected the project, the SRV-Stora Enso team was able to deliver the most cost-competitive proposal in comparison to the other members (PuuInfo, 2020*a*). The building *Eskolantie* then uses the same 3D modular "Urban MultiStorey" concept of the previous Stora Enso projects. The other project *DAS Kelo* was realised after the City of Rovaniemi set an architectural competition based on a circular economy strategy, aiming for a sustainable development (Woodarchitecture, 2020). In the project, several other public players were involved like the Lapland University of Applied Sciences, the University of Lapland, the Foundation's residents and student organizations, as well as Napapiirin Energia ja Vesi NEVE Oy.

In two other case-studies, the city zoning influenced the use of timber. This is the case of both *Wood City* and *Lighthouse Joensuu*. In the first case, *Wood City* was the result of a competition and the construction permit was won by the team SRV-Stora Enso (which previously built *Eskolantie*). The project introduces the updated CLT-based version of "Urban MultiStorey" system (PuuInfo, 2020*c*). The new concept introduced new product combinations with LVL, explaining the presence and use of this EWP (Hernández, 2018). The project saw Sweco and Woodcon get involved. Both the companies were involved in several case-studies in Norway. *Lighthouse Joensuu* was commissioned by Student Housing Oy Joensuun Elli, a public company. The requirement to build it with wood came from city zoning planning (Eero-Reijonen-Oy, 2018) (Keskisalo, 2018). The general contractor of the project was previously involved in *Pihapetäjä* and is the timber construction company Rakennustoimisto Eero Reijonen. Because the company wanted to build the entire structure of timber, the structural engineers had to come up with a tie down steel system, not used in Europe and more frequent in the North American market (Keskisalo, 2018). Stora Enso delivered both the CLT and the LVL necessary for the construction. According to Hernández (2018), LVL walls considered better suited for the tie-down systems, due to the space that they leave in-between their frame. According to the fire safety requirements, the surfaces are mainly covered with gypsum board.

The last two case-studies were realised thanks to the desire of private investors, and in both projects public universities were involved. *Pihapetäjä* was financed by the Foundation for the Promotion of Karelian Culture. Since the beginning, the building was part of a larger R&D project focusing on the study of the potential of timber construction in collaboration with the University of Eastern Finland which became a partner in the development phase of the *Pihapetäjä* project (PuuInfo, 2020*c*) (OOPEAA, 2020). The timber supplier and contractors are not the same of the previous projects, however, like the majority of case-studies in Finland, *Pihapetäjä* was built with 3D modular element. *Seinäjoen Tuohi* is the first project which uses the "Lakea Sydänpuu" (Lakea Heartwood) concept (Lakea, 2020). This new concept was created by Casagrande Laboratory (the architect of record of the project) and delivers the bathrooms as ready-made concrete volume elements, whereas the apartments are built assembling modules made of CLT elements.

OOPEAA Architects were the only architectural office which was involved in two case-studies. The engineering offices are less heterogeneous than the architects, with Sweco and A-Insinöörit Suun-

nittelu Oy which have been involved in three case-studies each, and Pertti Ruuskanen Engineering involved in two. All the case studies have a Finnish company as timber supplier. The company Stora Enso supplied the CLT of six (out of ten) case-studies. Stora Enso produced until 2019 all its CLT panels in Austria in its two production plants of Bad St. Leonhard and Ybbs (Jauk, 2017). A third production plant of CLT was completed in Gruvön, Sweden in 2019 (Jauk, 2017) and a fourth is planned to be realized in the Czech Republic (Stora-Enso, 2020). Space Elementti-Sampo Oy produced timber for two case-study. General contractors are all different except for the case of the team SRV-Stora Enso and Rakennustoimisto Eero Reijonen Oy which were both involved in two projects each.

Additionally, the fact that nearly all the projects were built under a protective tent is a way to smooth out the seasonal fluctuations, because the frame construction of houses is summer-focused. The weather in Finland therefore obliged the construction industry to pre-assembled systems in order to build all seasons and quickly. This also explains the high pre-fabrication and 3D elements high ratio on Finnish projects.

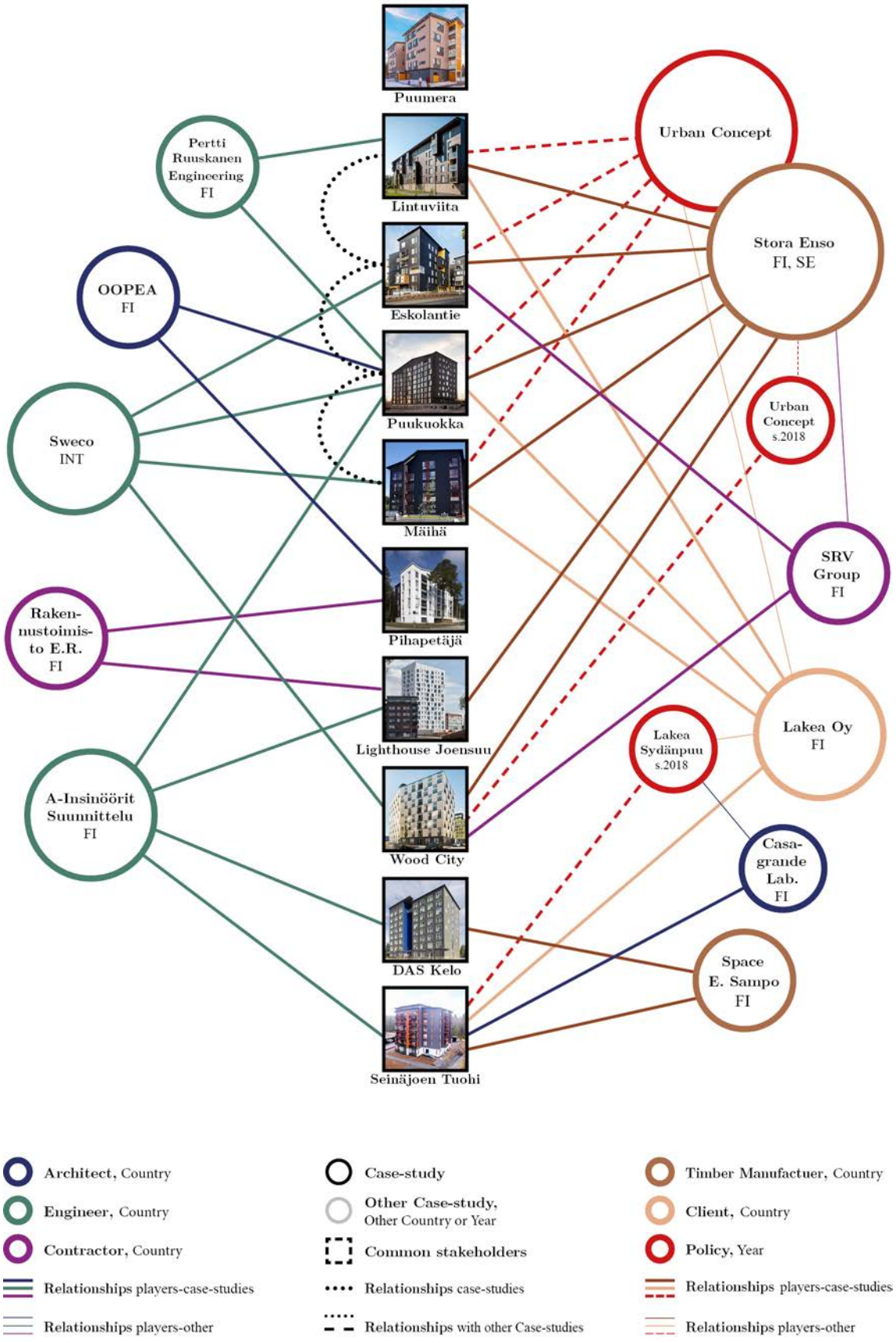

Figure 6.5: Relationships between Finnish case-studies, policies and their stakeholders

Table 6.3: List of players involved in Finnish case-studies

Project *(name)*	**Architect** *(name, country)*	**Engineer** *(name, country)*	**Timber Engineer** *(name, country)*	**General Contractor** *(name, country)*	**Timber Contractor** *(name, country)*	**Timber Supplier - Structural elements** *(name, country)*	**Timber Supplier - Floor slabs** *(name, country)*	**Client/Developer** *(name, country)*
Puumera	Vuorelma Arkkitehdit Oy, FI	Finnmap Consulting Oy - Insinööritoimisto Puolanne Oy, FI	Finnmap Consulting Oy - Insinööritoimisto Puolanne Oy, FI	Rakennusliike Reponen Oy, FI	Versowood Oy - Koskisen Oy, FI	Versowood Oy - Koskisen Oy, FI	Versowood Oy - Koskisen Oy, FI	City of Heinola, FI
Lintuviita	Arkkitehtitoimisto Matti, FI	Pertti Ruuskanen Engineering, FI	Stora Enso, FI, SE	Rakennus K. Karhu Oy, FI	Rakennus K. Karhu Oy, FI	Stora Enso, FI, SE	Stora Enso, FI, SE	Lakea Oy, FI
Eskolantie	Matti Iiramo Architects, FI	Sweco, INT	Sweco, INT	SRV Group - Stora Enso, FI	n/a	Stora Enso, FI, SE	Stora Enso, FI, SE	Helsinki City Housing Agency ATT, FI
Puukuokka	OOPEAA Office, FI	Pertti Ruuskanen Engineering, FI	SWECO, INT - A-Insinöörit Oy, FI	Keski-suomen Rakennuslinja, FI	n/a	Stora Enso, FI, SE	Stora Enso, FI, SE	Lakea Oy, FI
Mäihä	A-Live, FI	Sweco, INT	Insinööritoimisto Seinäjoen Rakennustekniikka Oy, FI	Insinööritoimisto Seinäjoen Rakennustekniikka Oy, FI	n/a	Stora Enso, FI, SE	Stora Enso, FI, SE	Lakea Oy, FI
Pihapetäjä	OOPEAA Office, FI	Insinööritoimisto Joensuun Juva Oy - Petteri Peltomaa, FI	Insinööritoimisto Joensuun Juva Oy - Petteri Peltomaa, FI	Rakennustoimisto Eero Reijonen Oy, FI	Rakennustoimisto Eero Reijonen Oy, FI	Pyhännän Rakennustuote Oy, FI	Pyhännän Rakennustuote Oy, FI	Foundation for the Promotion of Karelian Culture, FI
Lighthouse Joensuu	Arcadia Oy Arkkitehtitoimisto, FI	A-Insinöörit Oy, FI	A-Insinöörit Oy, FI	Rakennustoimisto Eero Reijonen Oy, FI	Rakennustoimisto Eero Reijonen Oy, FI	Stora Enso, FI, SE	Stora Enso, FI, SE	Student Housing Oy Joensuun Elli, FI
Wood City	Anttinen Oiva Arkkitehdit Oy, FI	Sweco, INT	Woodcon, NO, SE, AT	SRV Group - Stora Enso, FI	Woodcon, NO, SE, AT	Stora Enso, FI, SE	Stora Enso, FI, SE	Helsinki Housing Production, FI
DAS Kelo	Artto Palo Rossi Tikka Oy, FI	A-Insinöörit Oy, FI	A-Insinöörit Oy, FI	Lapinmestarira-kentajat Oy, FI	Space Elementti-Sampo Oy, FI	Space Elementti-Sampo Oy, FI	Space Elementti-Sampo Oy, FI	Domus Arctica Foundation - University of Lappland, FI
Seinäjoen Tuohi	Casagrande Laboratory Center of Urban Research , FI	A-Insinöörit Oy, FI	A-Insinöörit Oy, FI	n/a	Space Elementti-Sampo Oy, FI	Space Elementti-Sampo Oy, FI	Space Elementti-Sampo Oy, FI	Lakea Oy, FI

6.3.4 France

see Appendix pages 339-357

The majority of the case-studies in France are the result of private initiatives, but there are several examples where the public financed the projects. The influences were pretty heterogeneous: with the wish of the clients being the main reason projects were built in timber by the majority, however a considerable number of projects were completed based on the properties of timber, or a proposition by the design team.

Until 2010, in France it was not possible to build buildings more than two floors above the ground floor with a timber structure. This was due to lack of appropriate regulatory framework. In 2010, the regulatory framework was modified and since then, seven-storey buildings were allowed under certain conditions (under 28 meters). The new rules allowed the construction of the first French case-study. The design team of *Maison de l'Inde* had to answer three requests from the client, the Indian Government, which wanted to build new student housing for its Indian students. The first was to have an environmentally-friendly approach, the second was a compact construction because of the location of the building, the Cité Universitaire. The third was that it needed to be completed in twelve months (Lipsky and Gaujard, 2013). For these reasons the team originally thought to build the building as timber-3D modules. The design team ended up changing the structure to a more classical post-and-beam structure, due to the building site location (Paris) and the city traffic which made it difficult to guarantee a certain time schedule, risking affecting the budget (Lipsky and Gaujard, 2013). The Italian company Rubner supplied the EWPs used in the project.

Several other projects in France were built due to timber's properties. The goal of the public client of *Crous Jean Jouzel* was to build an economically and ecologically efficient building on a reduced timeline. In order to do so, Lignatec KLH (French sister company of KLH Austria) was involved in the project and applied its concept solution formed by CLT modules. Inside the building, only some structural timber walls are visible due to fire regulations. The engineer of record is the office Ingénierie Bois, founded in 2004 by an Austrian engineer. *Rue des Ardennes* was built with a timber structure because of the building site. The small plot of land was the major technical constraint of the project which is located far from the main street (Chroniques-architecture, 2016). The stakeholders came to the decision to build a building with a timber structure, to pre-fabricate the elements of CLT in the workshop, and to mount them on site. Woodeum was involved in the project as timber contractor and Stora Enso delivered the CLT. As the name suggests, Woodeum is a real estate developer who imagines, develops and markets sustainable buildings (Woodeum, 2020). The company is a founding member of the certification BBCA. Together with other French players committed to the climate, the Association pour le développement du Bâtiment Low Carbon (BBCA), aims to raise awareness of the urgent need to reduce the carbon footprint of the buildings. This independent association promotes all the approaches that contribute to the development of low-carbon buildings. Woodeum realised other low-rise timber-based buildings and is behind several other mid-rise and high-rise projects in France, which will be completed in the next 2020

decade (Woodeum, 2020).

Noise reduction properties and fast erection time (in addition to environmental reasons) were the main motives behind building *Lucien Cornil Student Residence* with timber. The public client CROUS, decided to build its new student housing projects in an urban area and wanted to have it ready to go for the beginning of the student's semester (Cervantes, 2018). *Green Office® Enjoy* was the first structure to be built with positive energy standards in Paris. The determining factor behind the choice of a hybrid timber-concrete-steel structure was the baseplate which, by serving as the load-bearing structure, had a limited load-bearing capacity at certain points. A traditional concrete structure was not possible due to its heavy weight. Therefore, the team opted for a hybrid structure, with timber as the prevalent material (Vaillé and Brisebourg, 2018).

Green Office® Enjoy was engineered by AIA Associés and developed by Icade, a large real-estate developer in France. Both the players were involved in several other French case-studies. The project *Jo&Joe* was initially developed in partnership with Woodeum. Woodeum then sold the building permit to Accor Hotels. For its new hotel concept called *Jo&Joe*, the Accor Hotels group selected the architectural firm Jean Paul Viguier, and the Basques Egoin delivered (and sometimes contributed to the installation) of the CLT (Batirama, n.d.). Timber was chosen in this case because of it's low noise emission which was welcomed in an urban environment.

Besides this consistent number of case-studies, another group of French projects were also built due to environmental reasons coming from private clients. The same players were involved in *Residences J.Ferry* which has a post- and-beam structure with CLT floor slabs. The private investor wanted to realise a passive building: the project is therefore a passive-house construction with class an A+ Energy certification which uses timber to meet the highest energy target. The facade has tiles in order to improve the fire-safety requirement (Gruber, 2013). *Ywood Les Docks Libres* was the first case-study built with CLT panels by the French timber manufacturer Mathis. The CLT panels were supplied by the Austrian company Binderholz, and the general contractor was Nexity. The architectural office Carta Associetes planned other timber projects and the owner was comfortable with the idea of realising a sustainable building. The project is based therefore on the BBS (CLT) Binderholz system (Bouquet, 2015). *Quai de la Borde* is a project of Wilmotte architects which was developed by Woodeum. The building has been selected to be one of the pilots of the new Low Carbon Building (BBCA) label, which Woodeum helped to create. The architectural office built another smaller CLT project after the positive experience they had with *Quai de la Borde*. Both Mathis and Stora Enso were involved in the project. *Pont de Flandres Batiment 007* was built due to the request of the client, which requested architect Anne Carcelen and AIA Ingénierie to design the building with timber (Woodsurfer, 2017) (Carcelen, 2020). Also in this project, Mathis was involved. *Pop-Up* is a social housing project in which the private owner requested to have a timber structure, and the building ended up being the winning project of an architectural competition (Divisare, 2017). Due to fire regulations, the structural timber surfaces had to be encapsulated in gypsum boards. Another project carried out by Icade was the 28,450 m^2 office *Pulse*. This project, one of the largest case-studies in this dissertation, was supplied by Mathis. Vinci Construction

France and Mathis delivered the building, built with a timber-concrete structure on behalf of Icade (Bruchon et al., 2019). Designed to be a new generation of business campuses on seven floors, *Pulse* is part of an environmental approach by obtaining HQE level Excellent and BREEAM level Very Good certifications (Cmpbois, 2019). This operation is also the largest office building to receive the BBCA label.

Besides the private initiatives already covered, several projects were realised thanks to the wish of a public client. *Bâtiment Max Weber* had a university client which had environmental goals for the design of the building from the very beginning. The public client *DDTM* wanted to build an exemplary building with a design which considered environmental issues. The solution was to build a timber building which had some areas with a concrete skin facade. *DDTM* was designed by AIA Engineering and implemented a new patent obtained by the office which used a load-bearing timber frame and a prefabricated concrete facade to stiffen the building. The EWPs were provided by Cruard Charpente, which was also involved in another case-study. The developer of the project was Woodeum. The *Opalia* project won an architectural competition meeting the very ambitious environmental specifications imposed by client SEMAPA, a Parisan development company owned mainly by the city of Paris (SEMAPA, 2020). The architectural office which won the competition made a pilot project in Sophia Antipolis in 2008. The timber concept was optimised for prefabrication, with integrated engineering and lower costs, which made it possible to realise *Opalia*. In the case of *Perspective*, the city of Bordeaux indicated timber as the material to be used in the ZAC Euratlantique (Robert, 2020), which also includes other hybrid timber projects still in the design phase by the end of 2019. The main reasons behind using LVL were its low weight and short construction time due to the high level of prefabrication. *Kibori* is an office building which is part of the ZAC Euronantes Gare. Kibori is part of a building complex composed of three buildings made by a competition, which gave it a fixed height. Its architecture follows a bioclimate approach. Timber is visible because of the architect, who believes in biophilic design, wanted to keep it exposed. Furthermore, it met the BREEAM certification (Ware, 2018).

On two occasions the design team influenced the completion of a timber structure. *Palazzo Nice Meridia* was chosen as the winner after an organised competition. The structural concept of the buildings was based on *Ywood Les Docks Libres*, and was previously developed by Nexity (Bouquet and Lehmann, 2018) (Lignum, 2020). Nexity submitted the building to the competition and won. The project also meets the highest French certification standards like BREEM and BEPOS.

The design phase of *Sensations* lasted several years and followed a competition. The competition, organised by the city of Strasbourg, set timber as the structure material and induced the design team to include timber suppliers in the early stages of design. The winning team *Sensations* proposed a structure which also included the facade in the stiffening strategy. The team proposed two structural options, with the final one being fire tested in front of the relevant authorities (Stuerwald, 2018).

The architectural office representation in the French case-studies is heterogeneous with only two

offices occurring twice: ArtBuild and ASP Architecture. Other influential offices in the French and international context such as Wilmotte & Associes Architectes, Jean-Paul Viguier et Associés or Lainse´ Roussel were involved in one case study. It's likely that in the future they will play a more relevant role [6]. Engineering offices are also heterogeneous in the records and again only two offices were repeatedly involved in more than one case study, with AIA Associés, which built three case-studies and Ingénierie Bois with three built case-studies as well. Timber suppliers are more homogeneous in comparison. The majority of the timber suppliers are foreign. The French companies provided all told eight case-studies with Mathis which supplied EWPs for four case studies, Cruard Charpente which supplied two case-studies and other companies which supplied in total the other two case-studies. The Austrian companies are well represented with KLH (throughout Lignatec KLH) which supplied six case-studies, and Binderholz supplied one case study. The other three timber manufacturers involved were Stora Enso, Rubner and Egoin, Stora Enso involved in three case studies, and Rubner and Egoin involved in one case study each. General contractors are also more frequent and are all French. Eiffage Construction was behind three case-studies and is still involved in new projects (Cmpbois, 2020), Nexity was involved in two case-studies, and Vinci Group, one of the biggest construction companies in Europe, was involved in two case-studies. The developer Icade was behind four case-studies, one together with Bouygues Immobilier which was involved in another case-study. CROUS was involved in two case-studies, as Woodeum.

[6] Jean-Paul Viguier et Associés is involved in the design of the hybrid timber-concrete-steel tower Hyperion in Bordeaux (Cmpbois, 2020) and the office Lainse´ Roussel is also involved in the design of other timber projects.

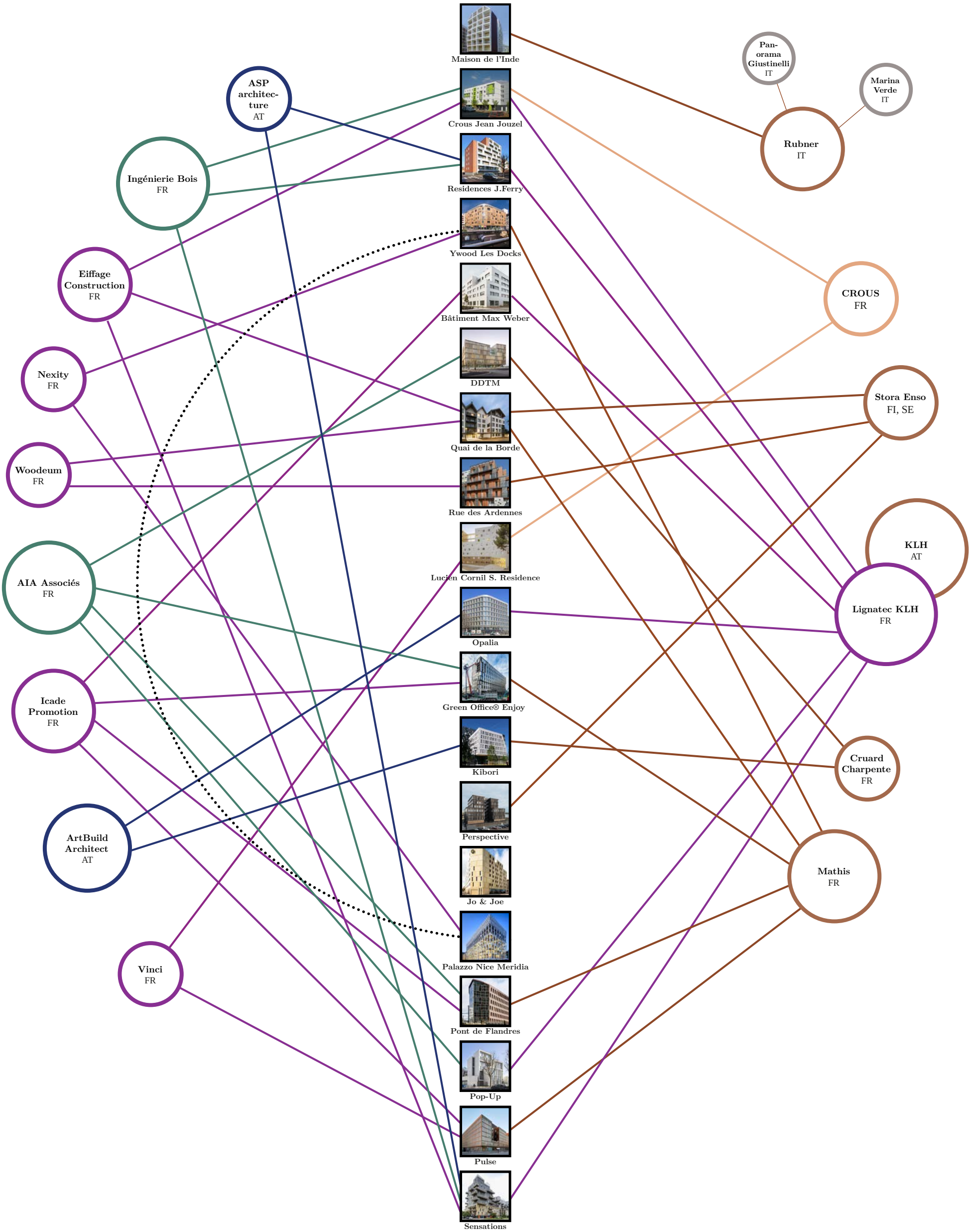

Figure 6.6: Relationships between French case-studies, policies and their stakeholders

Table 6.4: List of stakeholders involved in French case-studies

Project *(name)*	**Architect** *(name, country)*	**Engineer** *(name, country)*	**Timber Engineer** *(name, country)*	**General Contractor** *(name, country)*	**Timber Contractor** *(name, country)*	**Timber Supplier - Structural elements** *(name, country)*	**Timber Supplier - Floor slabs** *(name, country)*	**Client/Developer** *(name, country)*
Maison de l'Inde	Libsky Rollet Architects, FR	C&E ingénierie des structures, FR	C&E ingénierie des structures, FR	EGMB, FR	Rubner, IT	Rubner, IT	Rubner, IT	Maison de L'Inde - Indian Government, FR
Crous Jean Jouzel	Sourd-Durand Architectes, FR	Lapasserie Ingénierie, FR	Ingénierie Bois, FR	Eiffage Construction, FR	Lignatec KLH, FR	KLH, AT	KLH, AT	Crous (Poitiers), FR
Residences J.Ferry	ASP architecture, FR	Ingénierie Bois, FR	Ingénierie Bois, FR	Sertelet Yves, FR	Lignatec KLH, FR	KLH, AT	KLH, AT	Le Toit Vosgien, FR
Ywood Les Docks Libres	Carta Associés, FR	n/a	Mathis, FR	Nexity, FR	Binderholz, AT	Binderholz, AT	Binderholz, AT	Fonciere Inea, FR
Bâtiment Max Weber	Atelier Pascal Gontier, FR	SLH engineering, FR	KLH, AT	Icade Promotion, FR	Lignatec KLH, FR	KLH, AT	KLH, AT	Université Paris Ouest Nanterre La Défense, FR
DDTM	AIA Associés, FR	AIA Associés, FR	AIA Associés, FR	n/a	Cruard Charpente, FR	Cruard Charpente, FR	Cruard Charpente, FR	Préfecture du Morbihan, FR
Quai de la Borde	Wilmotte & Associés Architectes, FR	S2T, FR	Sylva Conseil, FR	Eiffage Construction, FR	Woodeum, FR	Mathis, FR	Stora Enso, FI SE	Woodeum, FR
Rue des Ardennes	Atelier Audebau - Fokkena, FR	Brezillon, FR	Les Charpentiers de l'Atlantique, FR	Brezillon, FR	Les Charpentiers de l'Atlantique, - Woodeum, FR	Stora Enso, FI, SE	Stora Enso, FI, SE	OGIF, FR
Lucien Cornil Student Residence	A-Architecture, FR	n/a	Arbonis, FR	Travaux du Midi (Vinci), FR	Arbonis, FR	Arbonis, FR	Arbonis, FR	Crous (Aix-Marseille Avignon), FR
Opalia	ArtBuild Architect, FR	SNC Lavalin (now Edeis), FR	SNC Lavalin (now Edeis) - Briand, FR	SNC Lavalin - Arcora - Quadrus - Briand, FR	Briand - Lignatec KLH, FR	KLH, AT	KLH, AT	SEMAPA, Buelens Real Estate, FR
Green Office® Enjoy	Baumschlager Eberle, INT	AIA Associés, FR	AIA Associés, FR	n/a	Mathis, FR	Mathis, FR	Mathis, FR	Bouygues Immobilier - Icade, FR
Kibori	ArtBuild Architect, FR	Novam Ingénierie, FR	ECTS, FR	ADI , FR	Cruard Charpente, FR	Cruard Charpente, FR	Cruard Charpente, FR	Sogeprom - BNP Paribas Real, FR
Perspective	Lainsé Roussel, FR	Terrell - Pouget Consultants - Ecotech - Emacoustic, FR	Terrell - Pouget Consultants - Ecotech - Emacoustic, FR	Pyrenees carpenters, FR	Pyrenees carpenters, FR	Piveteau bois, FR	Stora Enso, FI, SE	Pichet Promotion, FR
Jo & Joe	Jean-Paul Viguier et Associés, FR	Terrell, FR	Demathieu Bard, FR	Artelia Bâtiment et Industrie, FR	Demathieu Bard, FR	Egoin, ES	Egoin, ES	Accor Hotels, FR
Palazzo Nice Meridia	Marc Lehmann Architect, FR	Egis Concept - BG Ingénieurs, FR	CBS, FR	Cecaz - Groupe Nexity, FR	Lifteam, FR	Lifteam, FR	Lifteam, FR	Eco-Vallée Plaine du Var, FR
Pont de Flandres Batiment 007	Anne Carcelen architecte, FR	AIA Associés, FR	AIA Associés, FR	Spie batignolles - Mathis, FR	Mathis, FR	Mathis, FR	Mathis, FR	Icade Promotion, FR
Pop-Up	Wild Rabbits Architecture, FR	AIA Associés, FR	ICM - Artofact, FR	Charpente Cénomane, FR	Lignatec KLH, FR	KLH, AT	KLH, AT	OPH Aubervilliers, FR
Pulse	BFV architectes (Fassio Viaud Architectes), FR	Barthès , FR	Barthès , FR	Bateg - Vinci Construction France, FR	Mathis, FR	Mathis, FR	Mathis, FR	Icade Promotion, FR
Sensations	ASP Architecture - KOZ Architectes, FR	Ingénierie Bois, FR	Ingénierie Bois, FR	Eiffage Construction, FR	Lignatec KLH, FR	KLH, AT	KLH, AT	Bouygues Immobilier, FR

6.3.5 Germany

see Appendix pages 359-377

The similarities observed in Chapter 5 regarding some specific German projects can be easily analysed, considering that the architectural office Kaden-Lager was behind all of them. The idea of building *E3* started with three prospective buyers who involved architectural office Kaden-Lager Architekten because of their experience with timber projects (Käpplinger, 2009). The concept of the project was to form a "Baugruppe", a group of builders without developers which formed the premise for a co-housing development. In previous years, the building code of Germany and Berlin was changed, allowing buildings up to five-storey under specific requirements (Lattke and Lehmann, 2007) (Mahapatra et al., 2012). However, in all of Germany, all building approvals need to be discussed with the local authority (Mayo, 2015). *E3* was designed higher than the current rules allowed, and the architects had to involve fire brigades and fire consultants to convince the authorities to allow the construction of the project. Julius Natterer was involved as the timber engineer (see Section 3.3.2) and influenced the structural concept of the project. Besides the use of hybrid combinations, *E3* also used DLT for the floor slabs (Kaufmann et al., 2018). After *E3*, Kaden+Lager Architekten realized *C13*, *Famju* and *Skaio* which all share the same structural system of steel beams used in the external edge of the buildings. The client involved with *C13* visited the construction of *E3* and commissioned the architect to design a similar building (Kaden, 2021). The building requested by the client, needed to be as flexible as possible, which was facilitated by the resulting post-and-beam structure. Similarly, the public client of *Famju* and *Skaio* wanted to design a representative building for the newly developed area where the two projects are located (Kaden, 2021).

Besides *E3*, other co-housing concepts were behind the realisation of some German case-studies. Because of the ecological benefits of timber, the co-owner of *Prenzlauer Berg* wanted to have a timber structure (Jacob-Freitag, 2010). However, all timber elements are hidden due to fire regulations. The Austrian KLH provided the necessary CLT panels. The building is located in the same area of *E3*. *3XGrün* was built with timber at the request of the co-owners (Ballhausen, 2012). Furthermore, the building is the first implementation of a prefabricated prototype based on the research work "fertighauscity5+" which was developed at the Institute for Industrial Construction and Design (IIKE) of the Technical University of Braunschweig. This public-private joint venture led to the realisation of *3XGrün*. A similar joint-venture collaboration between public and private influences took place in *Holz8* (Mayo, 2015). Both the architect and the builder were previously involved in 2010 in the realisation of a smaller building with a similar system (*Holz4*). These buildings were supported by tests related to fire and building code standards. They were financed by the builder with the support of the program "From military wasteland to zero emission" of the Ministry of Economics and Technology (Mayo, 2015). The know-how gathered in the previous projects was transferred to *Holz8*. The core was made of concrete due to fire protection strategy. Involved in the project were all professionals which will reoccur in other German case-studies: the engineering office bauart Konstruktions and the timber contractor (and general contractor)

Huber&Sohn. The Austrian company, Binderholz supplied the CLT panels. The Italian company Rubner was involved in the realisation of *Walden 48*, which was the last example of co-housing built in Germany. Timber was used due to the request of the building owners (Rubner Holzbau, n.d.*b*).

Besides innovative co-housing, several other social housing projects were completed in Germany. *Wohnen Offenbach* and *Lynarstrasse Berlin* were both built by the company Holz Union (Seen, 2019). The engineer (and timber engineer) of record in *Wohnen Offenbach* was the Swiss office Pirmin Jung, and both of the clients in this case were public housing companies for social housing. The project *Lynarstrasse Berlin* utilised CLT panels form the Austrian company Binderholz. *WA14 West* and *WA15 West* are part of the same urban development carried out in Munich, in Prinz Eugene Park (Informationdienst Holz, 2020). The city of Munich set high environmental rules for this urban development and therefore the buildings needed a timber structure, which was the strategy chosen by the private investor (Opitsch, 2018). *WA15 West* was built with the strong influence of the company Huber&Sohn which provided several services, like timber construction and supply (Huber, 2019). *WA14 West* was supplied by the Austrian company Binderholz and Hasslacher Norica Timber. Rapp Architekten, which designed the project, already had an experience in designing timber buildings (Rapp, 2018).

Other projects were founded by German public institutions. *WoodCube* was built in Hamburg when the city was host of the International Building Exhibition (IBA), which is an initiative that supports builders in exploring environmental and socially responsible forms of urban development. In this regulatory context, the design team was confident in proposing a project with a timber structure. The structural concept of the structure, with load bearing external walls, allows for easy reconfiguration of the internal layout (Green and Taggart, 2017). Züblin Timber supplied the EWPs for the project *Wälderhaus*. The client was Schutzgemeinschaft Deutscher Wald (SDW), a public organisation for forests, whose focus is in education. No motivations for the project were found. Züblin Timber also supplied the EWPs for *Nachverdichtung Speyer*. Built for a public housing client, the building was engineered by Ingenieurbüro von Fragstein, which was also involved in *Famju* and *Skaio*. The company GEWOFAG Holding owned by the city of Munich financed the project *Dantebad*. The architect of record is Florian Nagler architekten, which in previous years, developed the idea of building above parking areas to face Munich's shortage of affordable flats. The timber structure of *Dantebad* is supported by a concrete ground floor which allowed the existing parking places to be used. The concept was then improved upon with the design of pre-assembled walls and floors which allowed the structure to be quickly erected (Herrmann, 2018) (Kaufmann et al., 2018).

The last three projects were all developed by private investors. The development of the *H7* projects is linked with the Life Cycle Tower One, which was supported by the Austrian government with the program "Haus der Zukunft" in cooperation with ARUP, the architect Hermann Kaufmann, and the company CREE by Rhomberg (Zangerl et al., 2010.) (Wiegand, 2019). The cooperation then resulted in the building *Life Cycle Tower* in Dornbirn (Austria). ARUP was involved in

H7 and there are similarities between the two built buildings, one being that they both relied on a concrete core and on a GLRS composed of glulam beams and concrete (Hein et al., 2016). The student residence *Woodie* was the result of an architectural competition which included the design team of the office Sauerbruch Hutton, the Austrian engineer office Merz Klay and the contractor Kaufmann Bausysteme. Both the program of the building and the Austrian know-how of Merz Klay and Kaufmann Bausysteme favoured the idea of a 3D modular structure. The CLT panels used in the 3D modules were delivered to Kaufmann Bausysteme by the Austrian Mayr-Melnhof (Kaufmann, 2018). The client and developer for the office *Kampa K8* is the company Kampa which builds prefabricated timber houses in Germany. The building was designed to be a celebration of timber technology (Kaufmann et al., 2018). Stora Enso supplied the necessary EWPs. The architect of record is the German architect Florian Nagler, who has a long tradition with timber projects and also planned the building *Dantebad*. The engineer of record was bauart Konstruktions, which was previously involved in the project *Holz8*.

Through the observation of the German stakeholders, it was discovered that a few architectural offices were involved in several case-studies. The office Kaden-Lager was involved in four case-studies, and was particularly important for the first case-study. Besides Kaden-Lager, Architect Florian Nagler was involved in two case-studies and the office had several timber projects which had been previously designed. Schankula Architekter were involved in *Holz4* before the realisation of *Holz8* and Rapp Architekten had experience in other smaller mass timber projects. As with other countries, the engineers were more involved in the case-studies in comparison with the architects. Bauart Konstruktions was involved as engineer in four case-studies, but was never the timber engineer. Instead, Ingenieurbüro von Fragstein was involved as timber engineer in three of the case-studies. The Swiss timber engineer office Pirmin Jung was involved in two case-studies. Half of the German case-studies were supplied by a foreign timber manufacturer whereas the other half was supplied by German producers. Züblin Timber supplied five case-studies, the highest number in Germany. All other suppliers supplied a maximum of two case-studies. Züblin Timber was also involved as general contractor in four case-studies with other relevant companies like Huber&Sohn and Holz Union which were involved as general contractors in two case-studies each. Four case-studies were financed by a co-housing initiative. Eight case-studies were the result of a private initiative. Public and private motivations to build a sustainable project were the main drivers behind the realisation of these projects.

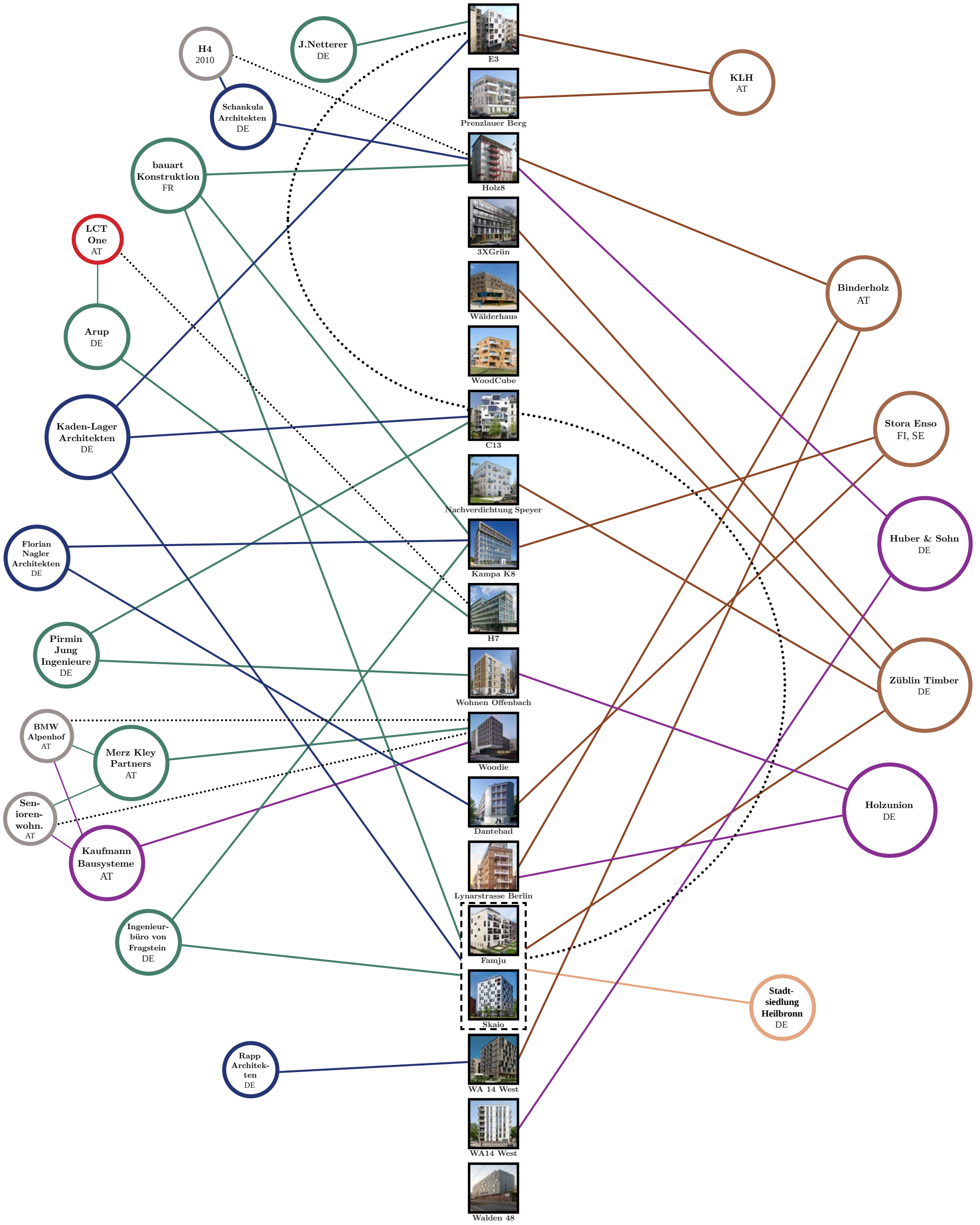

Figure 6.7: Relationships between German case-studies, policies and their stakeholders

Table 6.5: List of stakeholders involved in German case-studies

Project *(name)*	**Architect** *(name, country)*	**Engineer** *(name, country)*	**Timber Engineer** *(name, country)*	**General Contractor** *(name, country)*	**Timber Contractor** *(name, country)*	**Timber Supplier** **- Structural elements** *(name, country)*	**Timber Supplier** **- Floor slabs** *(name, country)*	**Client/Developer** *(name, country)*
E3	Kaden-Lager Architekten, DE	Bois Consult Natterer, CH	Bois Consult Natterer, DE - KLH, AT	n/a	KLH, AT	KLH, AT	KLH, AT	e3 Baugruppe, DE
Prenzlauer Berg	Müllers Büro, DE	Peter Wittig, DE	Prof. Dr. Rug. Wittenberge, DE	Kreutner & Schmälzlin, DE	ABA Holz van Kempen, DE	KLH, AT	KLH, AT	Baugruppe Zur Börse, DE
Holz8	Schankula Architekten, DE	bauart Konstruktions, DE	Huber&Sohn, DE	Huber&Sohn, DE	Huber&Sohn, DE	Binderholz, AT	Binderholz, AT	B&O Gruppe, DE
3XGrün	IfuH – Institut für urbanen Holzbau, et al, DE	ifb Frohloff, Staffa, Kühl, Ecker, DE	A-Z Holzbau, DE	n/a	Züblin Timber, DE - Metsä, FI	Züblin Timber, DE - Metsä, FI	Züblin Timber, DE - Metsä, FI	Baugruppe 3xgrün GbR, DE
Wälderhaus	Andreas Heller Architects & Designers, DE	Assmann Beraten-Planen, DE	Assmann Beraten-Planen, DE	Holzbau Heinrich Haveloh, DE	Holzbau Heinrich Haveloh, DE	Züblin Timber, DE	Züblin Timber, DE	Schutzgemeinschaft Deutscher Wald (SDW), DE
WoodCube	architekturagentur, DE	Isenmann Ingenieure , DE	Isenmann Ingenieure , DE	deep green development, DE	Thoma Holz101, DE	Thoma Holz101, DE	Thoma Holz101, DE	IBA Hamburg, DE
C13	Kaden-Lager Architekten, DE	Pirmin Jung Ingenieure, CH	Pirmin Jung Ingenieure, CH	Oa.sys, DE	Oa.sys, DE	n/a	n/a	Stiftung Bildung. Werte.Leben, DE
Kampa K8	Florian Nagler Architekten, DE	bauart Konstruktions, DE	Stora Enso, FI, AT	Kampa Beteiligungs, DE	Stora Enso, FI, AT	Stora Enso, FI, SE	Stora Enso, FI, SE	Kampa Beteiligungs, DE
Nachverdichtung Speyer	Schöne Architekten, Architekturbüro Schnieder, DE	Ingenieurbüro von Fragstein GmbH, DE	Ingenieurbüro von Fragstein GmbH, DE	Züblin Timber, DE	Züblin Timber, DE	Züblin Timber, DE	Züblin Timber, DE	Gewo Wohnen GmbH, DE
H7	Andreas Heupel Architekten, DE	Arup, DE	Arup, DE	Brüninghoff, DE	Brüninghoff, DE	Brüninghoff, DE	Brüninghoff, DE	DESRAD Immobilien, DE
Wohnen Offenbach	Hirschmueller Architektur, DE	Pirmin Jung Ingenieure, CH	Pirmin Jung Ingenieure, CH	B&O Wohnungswirtschaft, DE	HU-Holzunion, DE	HU-Holzunion, DE	HU-Holzunion, DE	Gemeinnuetzigen Baugesellschaft Offenbach (GBO), DE
Woodie	Sauerbruch Hutton, DE	Merz Kley Partners, AT	Merz Kley Partners, AT	PRIMUS developments - Senectus, DE	Kaufmann Bausysteme, AT	Mayr-Melnhof Holz, AT	Mayr-Melnhof Holz, AT	PRIMUS developments - Senectus, DE
Dantebad	Florian Nagler Architekten, DE	r.plan, DE	Ingenieurbüro Franz Mitterer-Mang, DE	E. Hönninger, DE	Huber&Sohn, DE	Stora Enso, FI, SE	Stora Enso, FI, SE	GEWOFAG Holding, DE
Lynarstrasse Berlin	Schäferwenningerprojekt, DE	Haussler Ingenieure, DE	Haussler Ingenieure, DE	HU-Holzunion, DE	HU-Holzunion, DE	Binderholz, AT	Binderholz, AT	Wohnungsbaugenossenschaft Am Ostseeplatz, DE
Famju	Kaden-Lager Architekten, DE	bauart Konstruktions, DE	Ingenieurbüro von Fragstein, DE	Züblin Timber, DE	Züblin Timber, DE	Züblin Timber, DE	Züblin Timber, DE	Stadtsiedlung Heilbronn, DE
Skaio	Kaden-Lager Architekten, DE	bauart Konstruktions, DE	Ingenieurbüro von Fragstein, DE	Züblin Timber, DE	Züblin Timber, DE	Züblin Timber, DE	Züblin Timber, DE	Stadtsiedlung Heilbronn, DE
WA14 West	Rapp Architekten, DE	Tragwerke-, DE	Tragwerke-, DE	Müllerblaustein HolzBauWerke, DE	Müllerblaustein HolzBauWerke, DE	Binderholz, AT	Hasslacher Norica Timber, AT	GWG München, DE
WA15 West	H2R-Architekten, DE	n/a	Huber&Sohn, DE	Huber&Sohn, DE	Huber&Sohn, DE	Huber&Sohn, DE	Huber&Sohn, DE	Bauen in Gemeinschaft, DE
Walden 48	ARGE Scharabi Raupach, DE	n/a	Rubner, IT	Die HolzBox, DE	Rubner, IT	Rubner, IT	Rubner, IT	Baugemeinschaft Walden 48, DE

6.3.6 Italy

see Appendix pages 379-391

The majority of the case-studies in Italy are the result of private initiatives (7 of 13). Public influence is also well represented with several social housing projects having been completed.

Before 2011, only three storey timber-based buildings were allowed in Italy. In 2011, the Building Code was changed, and removed all height restrictions (Presutti, 2013). This happened thank to *Cenni di Cambiamento* (Mayo, 2015). *Cenni di Cambiamento* was influenced by several players, both private and public. After the architectural competition awarded the winning project, the owner Polaris started to consider timber for the structure. After involving several consultants, and having visited the building site of *Residenza Sirio* in Switzerland, Polaris decided to build the project with timber (Fava, 2016). The Italian building rules at the time would have not allowed the realisation of the project, because of its height. For this reason, a process began which was brought forth by FederLegno (the main association of the timber construction in Italy) and the structural engineer Andrea Bernasconi. The goal was to get a derogation of the height limit imposed by the Italian building code for buildings like *Cenni di Cambiamento* (Mayo, 2015). The process to approve the derogation of the project took one year to enact, and was approved in 2011. Since then, in Italy, timber is considered on the same level as other construction materials (Fava, 2016). The construction team which won the permit to build *Cenni di Cambiamento* was composed of Borlini&Zanini, the Italian timber contractor Service Legno and the timber supplier Stora Enso, which all worked together previously on a six-storey Swiss case-study, *Residence Sirio*.

Thanks to the changes in the building code, the team of the case-study *Residence Alexander* could consider a timber structure for their project. The private client owned a hotel and wanted to re-qualify it as a residential building. In order to achieve the highest constructive result, the construction team decided to demolish it and build a new building. Because the area is highly seismic, the team opted for a concrete core with the rest of the structure made of CLT panels (Presutti, 2013). The same team, besides the architect, was involved in *Multipiano Coppito* which can be seen as a similar building. As with *Residence Alexander*, *Multipiano Coppito* is located in a highly seismic area and the team opted for the same structural concept used in the previous project.

Panorama Giustinelli and *Marina Verde* were both commissioned at the request of a private investor, who wanted to build a sustainable building, so much so, that both the projects have a CasaClima certification, which is one of the highest sustainability certifications in Italy (Promo Legno, n.d.) (Rubner Holzbau, n.d.*a*). The Italian timber manufacturer Rubner supplied and gave technical insight for both projects, which adopt similar solutions. At that time Rubner was not yet supplying CLT, which is why these projects have a post-and-beam structure.

After *Cenni di Cambiamento*, three other social housing projects were completed with a CLT structure. *Firenze Ex-Longinotti* was financed by the city of Florence, which wanted to provide affordable and healthy flats for the citizens (Vassallo and Pollari, 2018). An association of Italian

carpenters was involved and CLT panels from Stora Enso were purchased. The *5 per 5+1* project was designed in a similar context. The public housing agency of Trieste designed the building and created a competition for the realisation of five five-storey residential buildings with the desire of using CLT as the main material. The construction company which won the ban, proposed a combination of CLT and timber frames (based on glulam). The CLT floor panels were supplied by the Austrian company KLH and the Italian Xlam Dolomiti (Genero, 2019). Xlam Dolomiti is a company which is part of the Gruppo Paterno and supplied the CLT used in the Australian project *Gilles Hall*. In *Social Housing Vado Ligure* the main client, a private foundation, wanted to build a sustainable social housing for the city of Vado Ligure and therefore involved the city in the realisation of the five-storey building. The timber supplier and builder is the Italian Gandelli Group, which is a company specialized in timber construction and was involved in another early case-study in Switzerland, *Casa Montarina*, in 2007.

Other public initiatives were carried out in the city of Trento. The realisation of *Palazzina 5 piani* was the result of an international collaboration between ITEA[7], the University of Trento, the CNR-Invalsa[8] and the Canadian social housing company Quebec Societé D'Habitation. The goal of this international collaboration was to evaluate and compare the timber construction systems for social housing (Reynolds et al., 2015) (Moravi, 2020). Two companies of the Paterno Group (Legno Case and Xlam Dolomiti) were also involved in this project. In *Residenza Mayer* the professor Ario Ceccotti was involved in the engineering of the structure which was then constructed by an Italian company with a 3D modular system. This project was built thanks to the desire of the public client, the University of Trento (Essepi, n.d.). Professor Ario Ceccotti was involved in an international research called "SOFIE", which *"proved the suitability of multi-storey X-lam*[9] *structures for earthquake-prone regions* (Ceccotti et al., 2013).

The last three case-studies were all the result of private initiatives. Both *30 Wood House* and *GreenTorino* were built with timber at the request of the private clients to build a sustainable building (Ergodomus, n.d.) (ToArch Magazine, n.d.). *30 Wood House* was engineered by the Italian office Ergodomus which is specialised in timber structures nationally and internationally. The use of timber was proposed to the client by the architect of *Hotel Nautilus* (Gaudenzi, 2020). The repetitive hotel rooms, earthquake design and sustainability were all characteristics which led the client to favour a CLT structure (Gaudenzi, 2020). In this project the Austrian Mak Building and its partner Stora Enso were involved. As the fire regulations in Italy are really strict, *Hotel Nautilus* is the only Italian project with the timber ceilings visible in the rooms, which was the desire of the design team.

None of the architects involved in the case-studies were particularly experienced with timber structures, and it is indicative that none of the offices found were involved in other projects. Regarding the engineers, the situation is less heterogeneous with players like the engineer Agostino Presutti and EW-Engineering Works involved in two case-studies, and relevant figures like Borlini&Zanini,

[7]ITEA is a public housing agency of Trento

[8]CNR-Invalsa is the National Research Council of Italy on Trees and Timber

[9]X-lam is a term used in Italy to refer to CLT

Ergodomus and Prof. Ario Ceccotti which have a long experience with timber structures also internationally. In the other case-studies, the timber engineering part was carried out by the same timber supplier or contractor, which are represented more frequently by Forest Legnami, Mak Building and Gandelli Group. Eight of the thirteen Italian projects are supplied by Austrian manufacturer. Rubner and Xlam Dolomiti supplied three case-studies (*5 per 5+1* was supplied by both KLH and Xlam Dolomiti). The Italian company Rubner has however strong glulam and CLT production in Austria and is, like Stora Enso, an international company (also with sawmills in Germany and France).

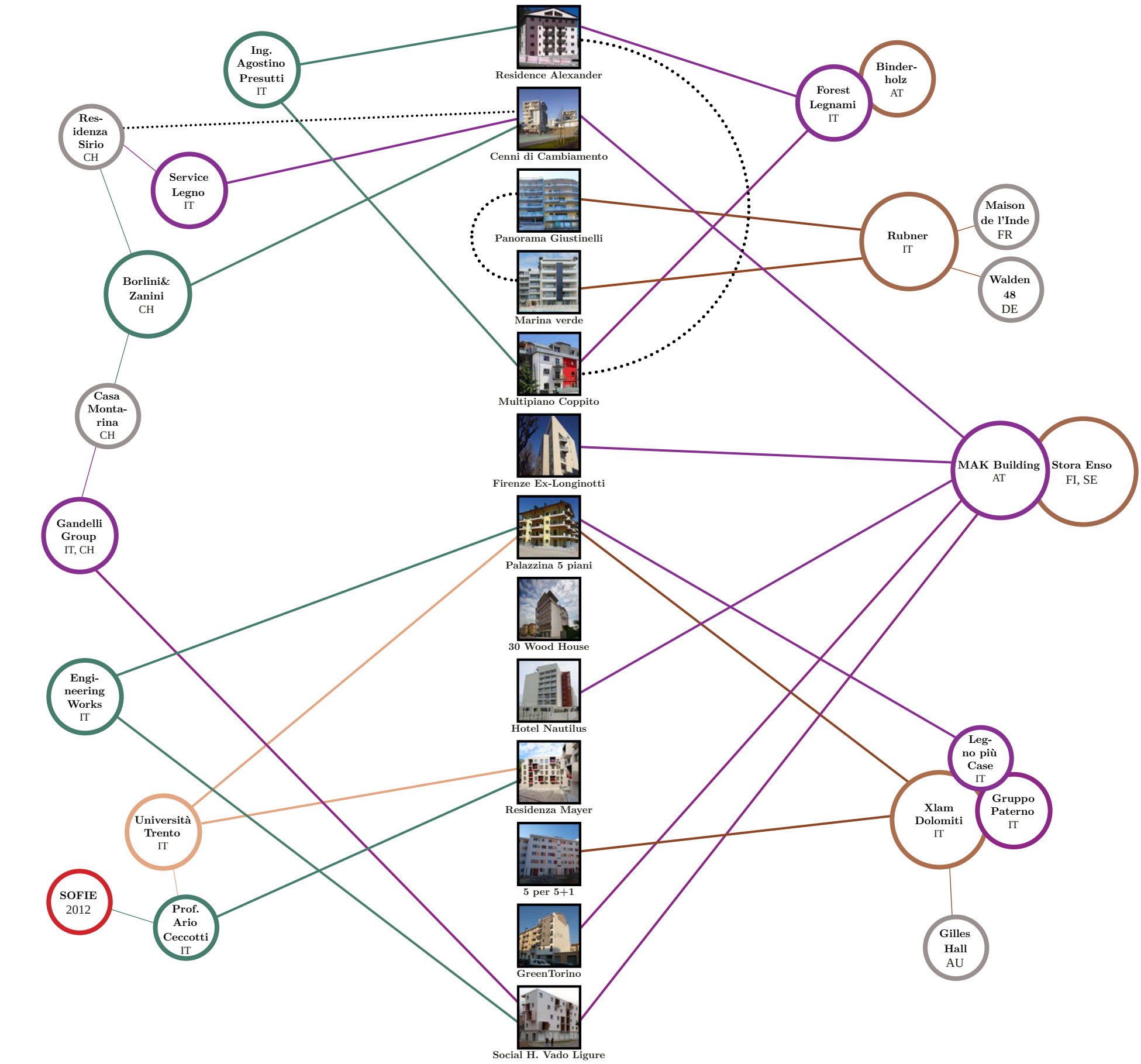

Figure 6.8: Relationships between Italian case-studies, policies and their stakeholders

Table 6.6: List of stakeholders involved in Italian case-studies

Project *(name)*	**Architect** *(name, country)*	**Engineer** *(name, country)*	**Timber Engineer** *(name, country)*	**General Contractor** *(name, country)*	**Timber Contractor** *(name, country)*	**Timber Supplier - Structural elements** *(name, country)*	**Timber Supplier - Floor slabs** *(name, country)*	**Client/Developer** *(name, country)*
Residence Alexander	Arch. Sebastiano Calabrò, IT	Idsingegneria Agostino Presutti, IT	Forest legnami, IT	n/a	Forest legnami, IT	Binderholz, AT	Binderholz, AT	GEIM, IT
Cenni di Cambiamento	Rossiprodi Associati, IT	Borlini&Zanini, CH	Borlini&Zanini, CH	Carron spa, IT	Service Legno, IT - MAK Building, AT	Stora Enso, FI, SE	Stora Enso, FI, SE	Polaris SGR - Comune di Milano, IT
Panorama Giustinelli	Epoca - Luciano Lazzari Architetto, IT	BDL Progetti, IT	Rubner, IT	Epoca, IT	Rubner, IT	Rubner, IT	Rubner, IT	Epoca, IT
Marina Verde	Simone Micheli - architectural hero, IT	Studio P&B Associati, IT	Rubner, IT	n/a	Rubner, IT	Rubner, IT	Rubner, IT	Marina Verde, IT
Multipiano Coppito	n/a	Idsingegneria Agostino Presutti, IT	Forest legnami, IT	Vittorini Emidio Costruzioni, IT	Forest legnami, IT	Binderholz, AT	Binderholz, AT	Vittorini Emidio Costruzioni, IT
Firenze Ex-Longinotti	Casa S.p.a., IT	Casa S.p.a., IT	Dedalegno, IT	Imola Legno - Campigli Legnami - Elettra Impianti, IT	MAK Building, AT	Stora Enso, FI, SE	Stora Enso, FI, SE	Comune di Firenze, IT
Palazzina 5 piani	Alberto Cristofolini Architetto, IT	EW-Engineering Works, IT	EW-Engineering Works, IT	Btd Servizi - Legno più case, IT	Gruppo Paterno, IT	Xlam Dolomti, IT	Xlam Dolomti, IT	Itea, IT - Canadian social housing Quebec Societé D'Habitation, CA
30 Wood House	Fabbricart Architetti Associati, IT	Ergodomus, IT	Ergodomus, IT	n/a	Foresti, IT	Mayr-Melnhof Holz, AT	Mayr-Melnhof Holz, AT	Gualdi, IT
Hotel Nautilus	Architetto Marco Gaudenzi, IT	Ing. Marchetti Rossi Attilio, IT	Stora Enso	Centrolegno di Fano, IT	MAK Building, AT	Stora Enso, FI, SE	Stora Enso, FI, SE	Eden Viaggi, IT
Residenza Mayer	Studio bbs architetti associati, IT	Prof. Ario Ceccotti - Ing. Mauro Croce, IT	Prof. Ario Ceccotti - Ing. Mauro Croce, IT	Essepi, IT	Essepi, IT	Essepi, IT	Essepi, IT	Opera Universitaria della Provincia Autonoma di Trento
5 per 5+1	n/a	Bodino, IT	Bodino, IT	Riccesi, IT	Bodino, IT	KLH, AT - Xlam Dolomti, IT	KLH, AT - Xlam Dolomti, IT	ATER Trieste, IT
GreenTorino	Maurizio Salerno Architetto	Ing. Fabio Mosca, IT	Tecnici.eu, IT	Isi - La Quercia Bioedilizia, IT	MAK Building, AT	Stora Enso, FI, SE	Stora Enso, FI, SE	Immobiliare Salerno, IT
Social Housing Vado Ligure	5-1AA, IT	EW-Engineering Works, IT	EW-Engineering Works, IT	Gandelli Group, IT	Gandelli Group, IT	Stora Enso, FI, SE	Stora Enso, FI, SE	Fondazione Domus - Comune Vado Ligure, IT

6.3.7 Norway

see Appendix pages 394-410

There are political, technical and economic factors which had an influence on the rapid spread of CLT as a building material in Norway, especially in student dormitories. One of the main drivers was the company Veidekke, Norway's largest building contractor. The success of the project *Palisaden* triggered a wave of student residential projects whose concepts were based on the CLT panelised system. The regular plans of the student housing projects, together with the influence of *Palisaden*, made the designers of the next projects keen to use CLT (Fourthdoor, n.d.*a*). Veidekke was part of this first development and implemented the experience gathered on customized solutions for regular housing construction (Faanes, 2017).

Until 1997 in Norway, it was not allowed to build buildings taller than three-storeys with timber due to a terrible fire which made thousands of people homeless. In 1997, the government updated the building code by adopting a functional-base building code which made it possible to consider alternative structural solutions with timber (Wiegand, 2019).

The first Norwegian case-study *Svartlamoen Housing* was the result of an open architectural competition organised in 2001 by the city housing agency. The declared goal was to experiment with new urban sustainability options for a social housing project (Triendl, 2005) (Fourthdoor, n.d.*a*). The competition requirements already suggested innovative use of timber and the entire timber structure was supplied by the Austrian company Santner (Triendl, 2005). Five years later, *Egnes Park* was completed. The project is located in Stavanger which in 2003 became the designated European Cultural Capital. In light of this event, the city increased their promotion of timber architecture, for which the city was historically famous. For this reason the Norwegian Wood Program was started, which supported several solid timber projects from 2004 until 2008 (Mayo, 2015). *Egnes Park* was between these projects and was commissioned due to an architectural competition. There were no fire issues with the local building authority thanks to the building's sprinkler system (Mayo, 2015). The Norwegian timber supplier Moelven, provided the timber knowledge and the structural timber elements. As a result of this project, several technical solutions were shared and used in other buildings (Mayo, 2015).

A real key-project in Norway, *Palisaden* student housing was completed in Ås in 2013 and started a wave of other student residential buildings all built with CLT (Nikolaisen, 2013). The Norwegian state was committed to cover 33% of the total cost of student housing projects if the total cost stayed under a certain sum[10]. With this regulatory context, the construction company Veidekke won the tender competition of *Palisaden*. During the building process for the project, the company realised that building with solid wood was all in all cheaper than prefabricated concrete elements, and felt confident in pursuing the realisation of the project with a timber structure (Nikolaisen, 2013). Commissioned by the public Student Service Foundation of Ås, the timber contractor was the Austrian company Raimund Baumgartner and the necessary CLT panels were supplied by the

[10]600,000 NOK per dormitory.

Austrian Meyr-Melnhof. Høyer Finseth was the engineering office which calculated the structure. Høyer Finseth is now part of WSP Engineering. iTRE was involved in the project as well. iTRE is an association of professionals and partners which promote solid timber in Norway (iTre, n.d.). The levels of public and media interest in this alternative and sustainable structure were rising. All the stakeholders involved, like building contractors, politicians and clients were all praised for their decisions, and other student organisations began to seriously consider CLT as a valid alternative for the construction of student housing in other cities (Nygaard, 2018). In addition, the Norwegian building code was updated. All the residential buildings with a lift had to be provided with a sprinkler system (Nygaard, 2018). This favoured timber even more, guaranteeing the possibility of having a mandatory sprinkler system which allows some structural timber to be exposed in the student rooms. A central role was also played by the student association. In Norway, they act as builders and operators of the buildings (Nygaard, 2018).

After *Palisaden*, the other nine student housing were completed in five years. Their construction was essentially made by two construction companies, Veidekke (eight case-studies) and Ove Skår (three case-studies). *Sørhauggate* was planned by the architectural office Helen&Hard. The firm became aware of the qualities of wood when they were commissioned to restore a number of traditional buildings in the centre of Stavanger. The office had already worked on other solid timber projects in Norway, and once commissioned by the owner, Helen&Hard proposed to build the project with timber (Helen&Hard, n.d.). The client agreed. The project built by Veidekke, was designed in collaboration with Høyer Finseth and iTRE. The Conservatives, the Progress Party, the Christian People's Party and the Liberal Party decided to finance *Studentboliger Remmen* (Nygaard, 2018). The project had a strong focus on sustainable construction and which is one of the reasons why the solid timber support system was designed in the project. The timber contractor Woodcon, which has a partnership with Stora Enso, built the project. *Studentboliger Remmen* was designed by BAS architects in collaboration with iTRE. The same team also designed *Bjølstad Studentboliger*, whose CLT panels were delivered by the Austrian Binderholz. The original design proposal in the architectural competition for *Moholt 50/50* was with a traditional concrete and steel structure. However, in order to meet the high energy standards set by the client, the team considered the possibility to construct the building with CLT panels. After several tests were made, the construction began and some timber structure surfaces were covered with gypsum boards in order to meet sound and fire requirements. Woodcon, Stora Enso, Moelven and Veidekke were all involved in the construction of this project.

As with previous case-studies, *Ringerike Campus*, *Øvre Sund* and *Fagerlund studenthybler*, were all commissioned by the student association and Veidekke constructed them. The common goal of these clients was to build sustainable buildings in line with the previous case-studies (Tunmo, 2016). Code was the architect of record for the projects, with Woodcon and Stora Enso supplying the CLT panels. WSP Engineering engineered the first two case-studies. *Dramsvegen* and *Kringsjå studentby* were designed by the same architectural office AT Plan & Arkitektur. The student housing project in *Dramsvegen* is part of a large national and multi-phase development with CLT (Woodcon, n.d.).

The first phase of the project was completed by Woodcon and the Austrian Baumgartner. CLT was supplied by Stora Enso. Büro Koppelhuber and Hoyer Finset were involved in the engineering of the buildings. *Kringsjå studentby* was built by Ove Skår AS and involved iTre and Mayr-Melnhof (Joelson, 2018). The competition had high sustainability standards and passive targets like many other previous student housing projects. The knowledge gained through *Moholt 50/50* created new competence and innovative strategies which were applied in *Maskinparken TRE*. The project consists of twin buildings commissioned by a private investor. One was built with traditional concrete and steel, and the other *Maskinparken TRE* with a solid wood structure (Eliassen et al., 2019*a*). The goal of this development was to show that the final cost is comparable (Faanes, 2017). Additional studies and research was done on the buildings, which, for example, compared the GHG emissions of the two buildings (Falch Aune, 2020). The results show that the CLT building has 25% lower GHG emissions compared to the concrete and steel building when looking at the production stage, and 13% lower emissions when looking at all stages (Eliassen et al., 2019*b*). WSP Engineering, Woodcon and Stora Enso were all involved in the project.

Parallel to these publicly financed projects, some other relevant private initiatives took place in Norway. However, it is worth mentioning that most of the time these private initiatives were supported by some indirect public funding especially for R&D. As noted in the previous chapter, *Treet* and *Mjøstårnet* have a similar structural system (Abrahamsen, 2017). These two projects based their structure on a system called "Trä8", a glulam and LVL structural system which was the result of a long R&D process which mainly involved the Norwegian timber manufacturer Moelven and the Luleå University of Technology (Parida et al., 2010) (Wiegand, 2019). The chance to develop EWPs for large span timber structures started in 1994, thanks to the Winter Olympic Games. Therefore, the company Moelven began an R&D program for long span truss structures (Wiegand, 2019). In 2005, a five-storey timber building was built in Trondheim based on the development of the truss structure, which was specially developed as columns in the building. With *Treet*, the local authorities relaxed the building code height limit and in general the project was realised during a wave of interest and Scandinavian polices which created a positive building environment (Goodland, 2016). Together with Moelven, the company Sweco was also involved in the erection and other engineering tasks. *Mjøstårnet* is the constructive evolution of *Treet* and the main reason for building *Mjøstårnet* was because it was the wish of the private client (Abrahamsen, 2018). Driven by sustainable interests, he commissioned the project directly to the design team led by Moelven. The choice to not use 3D modules like in *Treet*, was due to the need to have a much higher degree of flexibility, due to *Mjøstårnet*'s mixed use program (Abrahamsen, 2017).

The office *Bjergsted Financial Park* was the result of an architectural competition organised by the owner, SpareBank-Finansparken Bjergstad. From the beginning, the team, composed of architectural offices Helen&Hard and Saaha, Degree of Freedom, and the Swiss office Creation Holz (related to the company Blumer Lehmann) made it their goal to build the building with a timber structure (Rando, 2019). After winning the competition, the players teamed up and proposed the idea of building the office with timber to the client. In support of their idea, they selected a portion

of the building and analysed economically with two possibilities: steel/concrete and timber. The comparison showed that the difference in cost was 1,4% higher for timber (Rando, 2019). The team also organised a trip for the clients to visit to other timber buildings (*Tamedia* in Switzerland and *Illwerke Zentrum Montafon* in Austria) and created a mock-up of the future building. With these actions, the team successfully convinced the owner to switch to a timber structure because of its environmental benefits, the low economic difference, and internal aesthetics (Rando, 2019) (Kropf, 2019). According to the architect, Creazion Holz played a key role in the design of the timber structure. This is why the screw-less combinations used in the project are similar to the ones used in the Swiss case-studies *Tamedia Office* and *Omega Headquarter* (Kropf, 2019). Different combinations of EWPs (LVL and glulam) were also suggested by Creation Holz.

Finally, during one workshop in the initial phases of *Valle Wood*, the architectural office Lund+Slaato Architekter introduced the idea of building it with a timber structure (Lund Godbolt, 2020). The client NCC Property agreed to this idea, and it was mutually decided to go ahead with the design phases with a CLT-based concept. The Austrian KLH then supplied the CLT. All the remaining EWPs were provided by Moelven.

Through the analysis of the context of MTBs in Norway, it became clear that stakeholders, policies and clients are strongly interconnected. Several architectural offices appear in more than two case-studies, as well as many recurring engineering offices. Foreign offices like Creation Holz or Sweco are also present. Recurrent players are WSP Engineering (which acquired the timber engineering office Høyer Finseth), the consortium iTRE, and Sweco. The timber contractor Woodcon, together with the partner Stora Enso, was involved in the majority of the Norwegian case-studies. The general contractors Veidekke built eight case-studies, and Ove Skår built two.

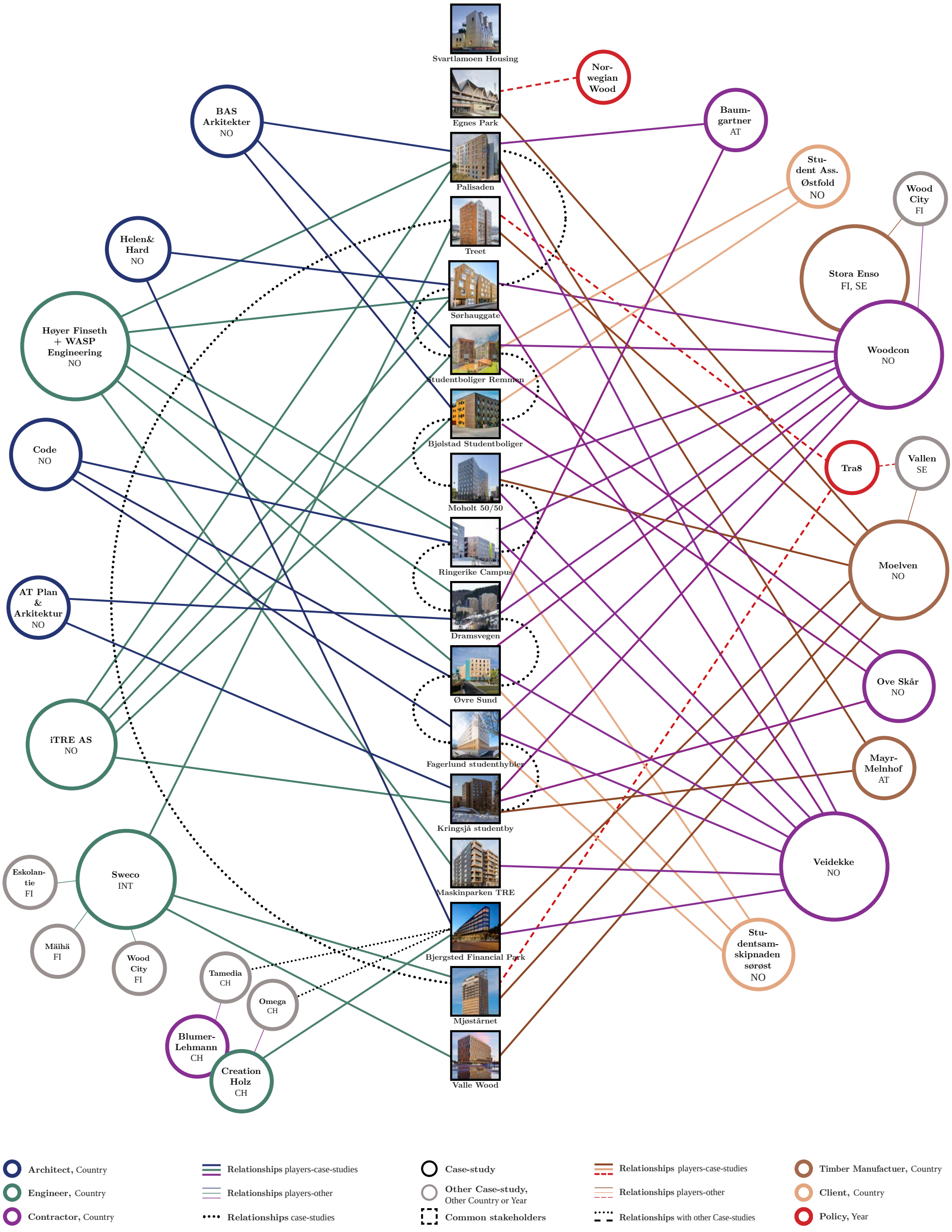

Figure 6.9: Relationships between Norwegian case-studies, policies and their stakeholders

Table 6.7: List of stakeholders involved in Norwegian case-studies

Project *(name)*	**Architect** *(name, country)*	**Engineer** *(name, country)*	**Timber Engineer** *(name, country)*	**General Contractor** *(name, country)*	**Timber Contractor** *(name, country)*	**Timber Supplier** **- Structural elements** *(name, country)*	**Timber Supplier** **- Floor slabs** *(name, country)*	**Client/Developer** *(name, country)*
Svartlamoen Housing	Brendeland & Kristoffersen arkitekter, NO	Reinersten Engineering, NO	Reinersten Engineering, NO	Stjern, NO	Santner, AT	Santner, AT	Santner, AT	Svartlamoen housing trust, NO
Egnes Park	Onix, NL - HLM arkitektur - NAL, NO	Moelven, NO	Moelven, NO	Tore Ravndal, NO	n/a	Moelven, NO	Moelven, NO	Svein Aase, NO
Palisaden	BAS Arkitekter, NO	Høyer Finseth , NO	Høyer Finseth, NO - iTRE, NO	Veidekke , NO	Raimund Baumgartner, AT	Mayr-Melnhof Holz, AT	Mayr-Melnhof Holz, AT	Student Service Foundation Ås, NO
Treet	Artec Architecture, NO	Sweco, INT	Moelven, NO	n/a, INT	Moelven, NO	Moelven, NO	Moelven, NO - Züblin Timber, DE	Bergen og omegn boligbyggelag, NO
Sørhauggate	Helen&Hard, NO - PPAG Architekten, AT	n/a	Multiconsult - Høyer Finseth - iTRE, NO	Veidekke , NO	Woodcon, NO, SE, AT	Stora Enso, FI, SE	Stora Enso, FI, SE	Student Welfare Organization of Stord Haugesund, NO
Studentboliger Remmen	BAS Arkitekter, NO	n/a	iTRE, NO	Ove Skår, NO	Woodcon, NO, SE, AT	Stora Enso, FI, SE	Stora Enso, FI, SE	Student Association in Østfold (SiØ), NO
Bjølstad Studentboliger	BAS Arkitekter, NO	n/a	iTRE, NO	Ove Skår, NO	n/a	Binderholz, AT	Binderholz, AT	Student Association in Østfold (SiØ), NO
Moholt 50/50	MDH Arkitekter, NO	Moelven, NO	Moelven, NO	Veidekke , NO	Woodcon, NO, SE, AT	Moelven, NO - Stora Enso FI, SE	Stora Enso, FI, SE	Studentsamskipnaden i Trondheim, NO
Ringerike Campus	Code, NO	WSP Engineering, NO	WSP Engineering, NO	Veidekke , NO	Woodcon, NO, SE, AT	Stora Enso, FI, SE	Stora Enso, FI, SE	Studentsamskipnaden sørøst-Norge, NO
Dramsvegen	AT Plan & Arkitektur, NO	n/a	Büro Koppelhuber, AT - Hoyer Finseth, NO	Econor, NO	Woodcon, NO, SE, AT - Baumgartner, AT	Stora Enso, FI, SE	Stora Enso, FI, SE	Norges Arktiske Studentskipnad, NO
Øvre Sund	Code, NO	WSP Engineering, NO	WSP Engineering, NO	Veidekke , NO	Woodcon, NO, SE, AT	Stora Enso, FI, SE	Stora Enso, FI, SE	Studentsamskipnaden sørøst-Norge, NO
Fagerlund studenthybler	Code, NO	n/a	n/a	Veidekke , NO	Woodcon, NO, SE, AT	Stora Enso, FI, SE	Stora Enso, FI, SE	Studentsamskipnaden sørøst-Norge, NO
Kringsjå studentby	AT Plan & Arkitektur, NO	n/a	iTRE AS, NO	Ove Skår, NO	n/a	Mayr-Melnhof Holz, AT	Mayr-Melnhof Holz, AT	Univeristy Oslo, NO
Maskinparken TRE	HUS Arkitekter, NO	WSP Engineering, NO	WSP Engineering, NO	Veidekke , NO	Woodcon, NO, SE, AT	Stora Enso, FI, SE	Stora Enso, FI, SE	Lilleby Eiendom, NO
Bjergsted Financial Park	Helen&Hard - Sahaa, NO	Degree of Freedom, INT - Creation Holz, CH	Degree of Freedom, INT - Creation Holz, CH	Veidekke , NO	Block Berge Bygg, NO	Hess Timber, DE	Moelven - Faber Bygg, NO - Pollmeier, DE	SpareBank - Finansparken Bjergstad, NO
Mjøstårnet	Voll Architects, NO	Sweco, INT	Moelven, NO	HENT, NO	Moelven, NO - Woodcon, NO, SE, AT	Moelven, NO - Stora Enso FI, SE	Metsä Wood, FI - Stora Enso, FI, SE	AB Invest, NO
Valle Wood	Lund-Slaatto Architetekter, NO	Sweco, INT Ing. Seim & Hultgreen, NO	Oslotre, NO	n/a	Beslagos, NO	Moelven, NO	KLH, AT	NCC Property Development, NO

6.3.8 Spain

see Appendix pages 412-416

The majority of the Spanish projects were developed and built thanks to private investors, with the exception of the social housing projects *Hondarribia Visesa VPO*. The reason were mainly the sustainability of timber structures in comparison with concrete and steel. Several case-studies are located in urban areas where logistics played a role: the CLT panels were a suitable solution for both the wish of the clients and the building plot challenges. Additionally, three projects were supplied by the timber suppliers KLH or Stora Enso.

Contralaminada was completed in 2014 by Altermatéria, a Spanish timber construction company which partnered with KLH and imported the CLT panels from Austria. No information was found on the motivations behind the realisation of this project. The same companies were also involved in the project *15 Buenavista*. The developer of *15 Buenavista* was Impacto Cero a company that works on the development of sustainable residential real estate in Spain. An association between b720 Fermín Vázquez Arquitectos and Impacto Cero was born with the goal of demonstrating that it is possible to design real estate developments with minimal environmental impact despite the regulation of Spain's building sector (Impact-0, n.d.). Besides *Contralaminada* and *15 Buenavista*, the engineer Miguel Nevado was engineer of record also of *La Borda*. The project used timber elements supplied by the Basque company Egoin. The project has for client a cooperative of tenants (similar to the German co-housing concept of "Baugruppe") who wanted a sustainable building and opted for a timber structure. The plot of *La Borda* is leased for 75 years by the Barcelona City Council and the owners pay a low rent for it (Sapiña, 2019) . *ARV8* was built thanks to the sustainable goal set by the client Tectonica. Stora Enso supplied the necessary CLT panels thanks to its collaboration with the local Madergia.

The public company Visesa built instead the only publicly financed project of Spain. The company builds social housing projects and *Hondarribia Visesa VPO* is, by end 2019, the largest CLT project in Spain. Furthermore, all the CLT panels are manufactured by the local company Egoin (Baumad, n.d.). Egoin supplied the timber also for other projects in Europe like the French case-study *Jo&Joe* in Paris and *Nordic Loft* in the London.

In the Spanish case-studies, all the architects of record are different. This is not the case for the engineers, as seen in Figure 6.10. The engineer Miguel Nevado was involved as timber engineer of record in three projects out of five. Three timber suppliers were involved: twice KLH and Egoin, and once Stora Enso.

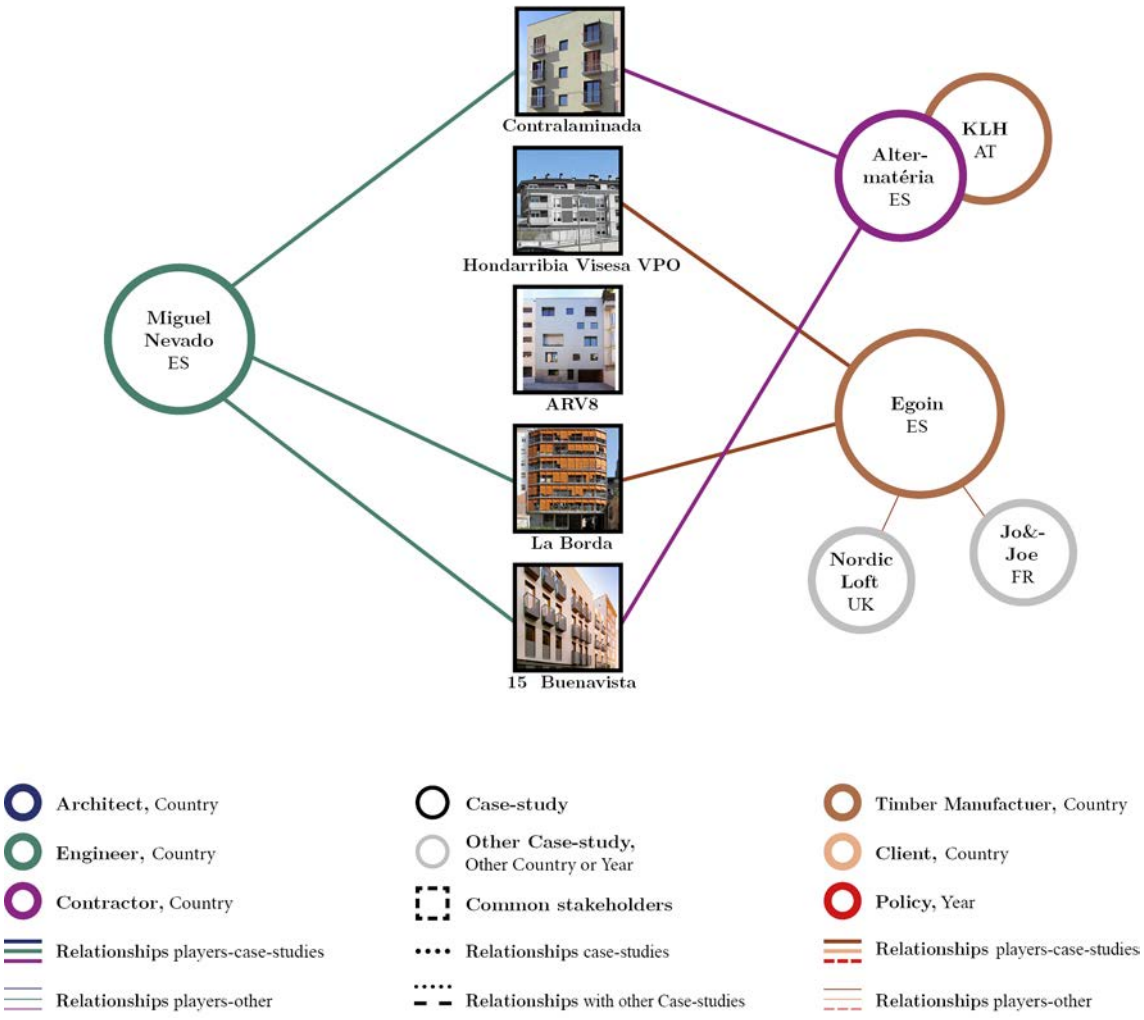

Figure 6.10: Relationships between Spanish case-studies, policies and their stakeholders

Table 6.8: List of stakeholders involved in Spanish case-studies

Project *(name)*	**Architect** *(name, country)*	**Engineer** *(name, country)*	**Timber Engineer** *(name, country)*	**General Contractor** *(name, country)*	**Timber Contractor** *(name, country)*	**Timber Supplier - Structural elements** *(name, country)*	**Timber Supplier - Floor slabs** *(name, country)*	**Client/Developer** *(name, country)*
Contralaminada	Ramón Llobera i Serentill, ES	Josep Cases i Roca, ES	Miguel Nevado, ES	Construccions Pallás, ES	Altermatéria, ES	KLH, AT	KLH, AT	Arrendaments Sandiumenge, ES
Hondarribia Visesa VPO	TYM asociados, ES	Egoin, ES	Egoin, ES	Visesa, ES	Egoin, ES	Egoin, ES	Egoin, ES	Visesa, ES
ARV8	Ábaton Arcquitectos, ES	Madergia, ES	Madergia, ES	Madergia, ES	Madergia, ES	Stora Enso, FI, SE	Stora Enso, FI, SE	Madergia, ES
La Borda	Lacol, ES	Miguel Nevado, ES	Miguel Nevado, ES	MCM Projects, ES	Egoin, ES	Egoin, ES	Egoin, ES	La borda cooperative, ES
15 Buenavista	b720 Fermín Vázquez Arquitectos, ES	Miguel Nevado, ES	Miguel Nevado, ES	Impacto Cero, ES	Altermatéria, ES	KLH, AT	KLH, AT	Impacto Cero, ES

6.3.9 Sweden

see Appendix pages 419-433

In the Swedish case-studies, both public and private influences were observed. A relevant driver for the realisation of these buildings was the city of Växjö, which for many years promoted the construction of MTBs in specially developed areas, with the clear intent of being a "timber city".

Due to changes in the Swedish design code in 1994, timber construction was no longer limited to two-storey buildings as it was before (Falk, 2005). This change induced a first series of R&D Programs which explored some of the first approaches to MTBs by both industry and universities. From the beginning, the Swedish government or the municipalities of some cities were involved in most of the case-studies. After a series of built projects described in Section 3.3.4, the first case-study considered is *Sundsvall I*. The project was the first part of a two-stage development with the goal of researching new timber uses and technical solutions. The entire development was studied and documented by the Luleå University of Technology which formed a joint venture with NCC Construction Sverige (Falk, 2005).

The city of Växjö initiated a program called "Mer trä i byggandet"(more timber in construction) in 2005. The goal of the program was to make timber an alternative to the construction of new buildings. An additional goal was to make the city a "timber city", by specifically increasing the number of high-rise buildings (Johansson and Schauerte, 2015). Thanks to this initiative, several projects in the city of Växjö benefited from this municipal policy. *Limnologen* was the first project. Its structure was in part realised due to the poor soil conditions of the building site (Serrano, 2009). A concrete basement was necessary to give a rigid base to the building's structure. The timber company Martinsons which previously invested in the production of CLT, supplied the CLT panels. Additionally, the design team decided to equip the entire project with sprinklers. Even if it was not necessary, this allowed some improvements in the building like the wooden facade, wooden balconies and the reduced space between the windows (Landel, 2018). *Portvakten* was built in Växjö as well, and was included in the program. The building is the result of a collaboration between Hyresbostäder, a public housing company, and the Energy Agency for Southeast Sweden (Kuzman and Sandberg, 2017) (Landel, 2018). NCC, participated as general contractor whereas Martinsons, contractor and supplier of the timber structure, improved the system used in *Limnologen*. The main goal of the partnership was to build one of the best performing passive-houses in Sweden with a very low energy consumption. For this target, solid wood was considered the best structural solution (Landel, 2018).

The system called "Trä8" developed by Moelven was instead applied to *Vallen* (Parida et al., 2010). Built in Växjö by GBJ Bygg and Värends Entreprenad AB, the client of the project was Växjöbostäder, which is one of two public housing companies in the Växjö municipal group. Växjöbostäder wanted a sustainable building and therefore *Vallen* was planned with timber (Johansson and Schauerte, 2015) (Linderholm, 2020). LVL floors were used because they are necessary for the LLRS of the Trä8 system. Structural timber is enveloped in gypsum boards due to fire regula-

tions. It could have been left exposed if the building had been designed with a sprinkler system, but this was considered too expensive by the team (Landel, 2018). The same client also directly commissioned the student housing *Docenten* (Thorsell, 2018). Not much information was found on the project. The building was constructed by GBJ Bygg, who also built *Trummens Strand* and *Strandsnäckan*, both completed in 2019. *Trummens Strand* was built in a part of the city of Växjö which was specifically assigned to be built with timber (Fojab, n.d.) (Johansson, 2020). Due to fire protection, only few walls could be left exposed (Tenje, 2018). *Strandsnäckan* was privately commissioned for environmental reasons and was built with timber due to the wish of GBJ Bygg AB (Linderholm, 2020). Another project *Ekologen* was planned from the beginning to be built with a timber structure (Thorsell, 2018). It was the contractor Värends Entreprenad (involved in the construction of *Vallen*), which decided to build the project with a timber structure. However, to fire regulations, the CLT walls are all enveloped with gypsum boards. The building was developed by Midroc Property, the same company which was involved in the construction of *Limnologen*.

Different influences were observed in the other Swedish case-studies. In 2004, the Swedish Government initiated a national timber construction strategy, with Skellefteå Municipality as an active participant (Wiegand, 2019). Martinsons, Lindbäcks Bygg AB and White Arkitekter AB were all involved from the start on the project called *Älvsbacka Strand*. The goal of the collaboration was to *"develop a new system for multi-storey buildings in wood with a strong industrial element."* (Skellefteå Municipality, n.d.). The team opted for 2D pre-assembled elements which were then assembled on site (Skellefteå Municipality, n.d.).

The two buildings of *Strandparken* were part of an urban development involving several other buildings. Wingårdhs Arkitekter, designed the buildings with a timber structure and the contractor Folkhem, even if it only had experience with smaller projects, decided to build them. The company set a parallel training area where the employees could familiarize themselves with the system (Green and Taggart, 2017). Martinsons joined the team and supported them in the engineering design and supplied the material.

The project *Åsbovägen* was based on the concept "Wood Right Through" for the municipal housing company FRIBO. The structure is composed of CLT panels delivered by KLH. By having sprinklers, the building was allowed to have some technical changes in the building code, like having a wooden facade, and some visible CLT surfaces inside the building (Landel, 2018). *Åsbovägen* became a significant reference project for Tengbom within sustainable living. According to the architect, it disproves the economic scepticism surrounding wooden buildings and provides a strong argument for similar projects in the future.

The developer Lindstén Fastigheter secured the building site where *Valla Berså* is constructed. The company wanted to build a sustainable and timber building (Wallén, 2020). Therefore, it involved Martinsons in the project, who also supplied the EWPs for the project.

Two projects were designed by two of the biggest architectural offices of Scandinavia, White Architects and C.F. Møller Architects. The project *Frostaliden*, designed by White Architects, is built

in a district of the city of Skövde which is dedicated to timber buildings (White Arkitekter, n.d.*a*). Several MTBs were built in the area, however, not much data on these MTBs could not be found. The residential area is part of "Wood City 2012", a joint project by 16 municipalities to decrease the environmental impact of the construction sector. Because the architects wanted to show off the timber structure, the two buildings which make up *Frostaliden* have sprinkler systems. Fristad Bygg was the turnkey contractor for the project and designed the CLT structure. The developer and contractor of *Kajstaden* wanted to build a timber building and asked C.F. Møller Architects to design it (ArchDaily, n.d.*b*). C.F. Møller Architects had a long history of R&D architectural projects on MTBs, having proposed several prototypes over the last several years (C.F. Møller Architects, n.d.) Even if the developer and the contractor did not have timber experience, they decided to embrace the project supported by Martinsons, which supplied the CLT used in the project (ArchDaily, n.d.*b*).

The project *Botanikern* was the answer to a call for sustainable initiatives in the architecture and development of a new neighbourhood in Uppsala called Rosendal (Axelsson, 2020). The timber structure was the basis of the design concept set by the city. Axeloth Arkitekten participated with Genova Property Group in 2014 and won the land allocation competition. The design managed to leave CLT cores, walls, and in the ceiling visible. CLT panels were supplied by the Latvian sawmill of the Skonto group, who also built the building.

Several recurring architectural offices were involved in the realisation of some Swedish case-studies. White Architekter, one of the biggest Scandinavian architectural offices, was involved in three case-studies. ArkitektBolaget also were involved in three case-studies. C.F. Møller Architects were involved in several R&D projects like HEB 2023, and built one case-study. Scarce information was found on engineers or timber engineers in the Swedish case-studies. The engineering office Projektbyggare was involved in the last two case-studies. Oftentimes, the timber engineers of record were the same companies which then supplied the timber, like in the case of the first five built case-studies where the company Martinsons provided both engineering and the EWPs. In total, eight case-studies were built with Martinsons EWPs and the other four projects were built with foreign timber suppliers (three by Austrian suppliers, and one by Moelven). The general contractors also tended to be repetitive. GBJ Bygg was involved in four case-studies, and eight other case studies were built by recurring contractors. Finally, the clients also tended to reoccur. Several builders were also clients in some projects.

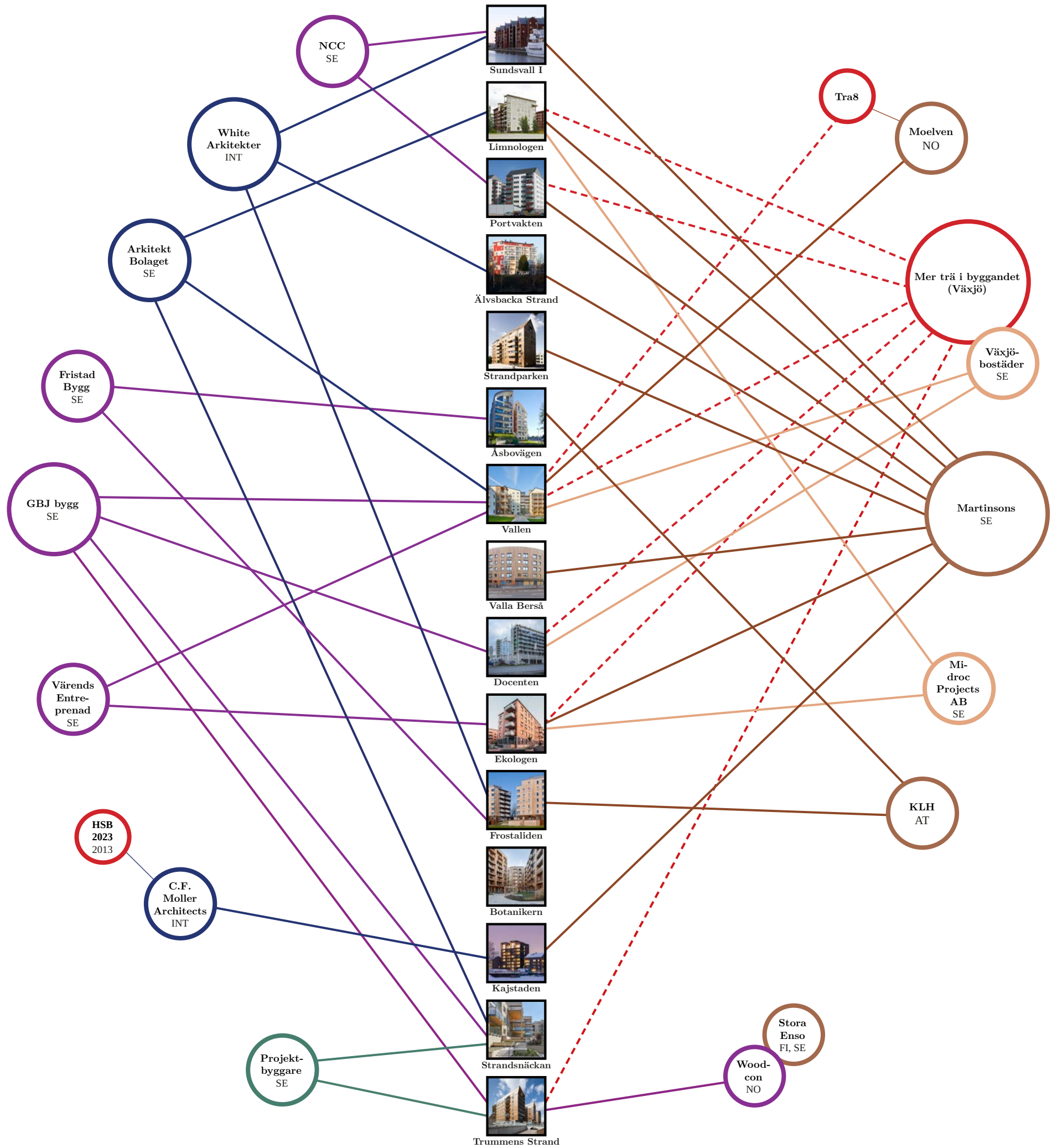

Figure 6.11: Relationships between Swedish case-studies, policies and their stakeholders

Table 6.9: List of stakeholders involved in Swedish case-studies

Project *(name)*	**Architect** *(name, country)*	**Engineer** *(name, country)*	**Timber Engineer** *(name, country)*	**General Contractor** *(name, country)*	**Timber Contractor** *(name, country)*	**Timber Supplier - Structural elements** *(name, country)*	**Timber Supplier - Floor slabs** *(name, country)*	**Client/Developer** *(name, country)*
Sundsvall I	White Arkitekter, INT	WSP Byggprojektering, SE	Martinsons, SE	NCC Construction Sverige, SE	Martinsons, SE	Martinsons, SE	Martinsons, SE	NCC Construction Sverige - Luleå University of Technology, SE
Limnologen	ArkitektBolaget, SE	Tyréns, SE	Martinsons, SE	Midroc Projects, SE	Martinsons, SE	Martinsons, SE	Martinsons, SE	Midroc Property development, SE
Portvakten	BSV Arkitekter & Ingenjörer, SE	BSV Arkitekter & Ingenjörer, SE	Martinsons, SE	NCC Construction Sverige - JSB, SE	Martinsons, SE	Martinsons, SE	Martinsons, SE	Hyresbostäder, SE
Älvsbacka Strand	White Arkitekter, INT	Lindbäcks Bygg, SE	Martinsons, SE	Bygg i Trä, SE	Martinsons, SE	Martinsons, SE	Martinsons, SE	Bygg i Trä, SE
Strandparken	Wingårdhs Arkitekter, SE	n/a	Martinsons, SE	Folkheim, SE	Martinsons, SE	Martinsons, SE	Martinsons, SE	Folkheim, SE
Åsbovägen	Tengbom, SE	n/a	n/a	Fristad Bygg, SE	Fristad Bygg, SE	KLH, AT	KLH, AT	Fristadbostäder, SE
Vallen	ArkitektBolaget, SE	Martin & Co, SE	Moelven, NO	GBJ bygg - Värends Entreprenad, SE	n/a	Moelven, NO	Moelven, NO	Växjöbostäder , SE
Valla Berså	Winell & Jern Arkitekter, SE	Gärderup Byggkonstruktion, SE	Martinsons, SE	Åhlin Ekroth Byggnads, SE	Martinsons, SE	Martinsons, SE	Martinsons, SE	Lindstén fastigheter, SE
Docenten	LBE Arkitekt, SE	n/a	n/a	GBJ Bygg, SE	n/a	n/a	n/a	Växjöbostäder, SE
Ekologen	Arkitektlaget, NO	n/a	n/a	Värends Entreprenad, SE	Martinsons - Bjerking, SE	Martinsons, SE	Martinsons, SE	Midroc Property development, SE
Frostaliden	White Arkitekter, INT	n/a	Fristad Bygg, SE	Fristad Bygg, SE	Fristad Bygg, SE	KLH, AT	KLH, AT	Brunnen Bostad, SE
Botanikern	Axeloth Arkitekter, SE	Skonto Prefab, LV	Daniel Fagerberg, SE	Skonto Prefab, LV	Skonto Prefab, LV	Cross Timber Systems (Skonto), LV	Cross Timber Systems (Skonto), LV	Genova Property Group, SE
Kajstaden	C.F. Møller Architects, INT	Bjerking, SE	Martinsons, SE	Consto, SE	Martinsons, SE	Martinsons, SE	Martinsons, SE	Slättö Förvaltning, SE
Strandsnäckan	ArkitektBolaget, SE	Projektbyggare, SE	Binderholz, AT	GBJ Bygg, SE	Binderholz, AT	Binderholz, AT	Binderholz, AT	BATTEN fastigheter, SE
Trummens Strand	Fojab Arkitekter, SE	Projektbyggaren, SE	Woodcon, NO, SE, AT	GBJ Bygg, SE	Woodcon, NO, SE, AT	Stora Enso, FI, SE	Stora Enso, FI, SE	GBJ Bygg, SE

6.3.10 Switzerland

see Appendix pages 435-453

Several key-players emerged from the analysis of the context of the Swiss case-studies. The first is the company Blumer Lehmann, an experienced timber company which provides both engineering services, and is also a supplier. The company was involved in many Swiss case-studies, as well as one Norwegian case-study. Besides Blumer Lehmann, other general contractors were key-players like Renngli, Implenia, and Erne.

Thanks to the newly developed technical and methodological principles in Switzerland, it has been possible to build timber structures with up to six storeys since the beginning of 2005. Eight-storeys have been allowed since 2015 (Oliver and Venables, 2012) (Mayo, 2015). Many case-studies were built according to Minergie standards, which is a sustainable certification in Switzerland (Makiol-Wiederkehr, 2020). Additionally, cities like Zurich implemented similar programs, such as the 2000-watt[11], which was added to the city municipal code in 2005. This led to increased requirements in energy efficiency and opened up some opportunities for timber construction.

The first case-study and two other projects were built by the Swiss contractor Renngli, who is specialized in prefabrication and timber buildings. Renngli built several smaller buildings before *Holzhausen*, and was involved in the realisation of *Siloah* and *Zollfreilager Housing*. Based on their own positive experience and ecological conviction, the client of *Holzhausen* decided to build a timber structure (Affentranger, 2009). Thanks to new fire regulations introduced some years before the completion of *Siloah*, all types of building programs can be built in Switzerland with timber as structural elements. This is why *Siloah*, the only hospital case-study, was built with a hybrid timber structure (Lipsky and Gaujard, 2006). Because the building was over a certain size, a sprinkler system was considered necessary. The choice of a hybrid timber structure was also favoured by the client, who needed construction to be quick, and noise emissions to be low. Noise emission was especially important because the new building was being constructed on a hospital campus. The timber engineer was the office Makiol+Wiederkehr which was involved in two other case-studies: *Holzhausen* and *Mühlebachstrasse*. The *Zollfreilager Housing* is part of a new urban development area in Zurich. The architectural office Rolf Mühlethaler Architekt won the competition but did not specify the structure of the buildings. The decision to construct the project with a hybrid timber-concrete structure came afterwards, and was facilitated by the regular shape of the buildings, and by the experience that the contractor Renngli had in utilizing pre-assembled construction (Mühlethaler, 2011). For fire protection reasons, nothing of the timber structure can be seen inside. Timber construction engineers were Indermühle, which were also involved in the *Giesserei* project.

Two projects *Casa Montarina* and *Residenza Sirio* were built in the Italian region of Switzerland and both were engineered by the Swiss office Borlini&Zanini. The projects were supplied by Stora

[11] The 2000-watt society is an energy policy model of the ETH Zurich, whose goal is to have an energy consumption of 2000 watts per citizen of the earth

Enso. The two contractors were Italian timber companies (Gandelli Group and Service Legno) which appeared in other Italian case-studies. Structurally, the projects are not similar and *Casa Montarina* is the only Swiss project which does not have the core made of concrete. The project is also one of smallest built case-study (950 m^2). The building *Casa Montarina* was built to meet the sustainable target Minergie in Switzerland and because the clients wanted to develop a building which was sustainable (Felder, 2009). The project *Residenza Sirio* was built thanks to the desire of the client and the designers decided to not expose the CLT inside (Fava, 2020). Borlini&Zanini and Service Legno will later form a team with Stora Enso, for the winning proposal of the biggest Italian case-study *Cenni di Cambiamento*.

Giesserei and *sue&til* are some of the largest MTB-developments in Switzerland and in the world. Both the projects are the result of an architectural competition, whose requirements gave high importance to sustainability (besides meeting Minergie targets) (Axel, 2013) (Lignum, 2013). The city organised the competition which was won by Galli Rudolf Architekten. Implenia built the large development with EWPs supplied locally (Axel, 2013). In 2013 the building was acquired by Allianz Suisse, which later developed *sue&til*. The building is near *Giesserei*. This even larger development was also built by Implenia. From the very beginning the project was designed with a timber structure due to the client's request (Lignum, 2019*a*). Thanks to its design, the building met the SIA Energy Efficiency Path 2040.

As said at the beginning, Blumer-Lehmann was involved in several projects. *Tamedia Office* and *Omega Headquarters* were both designed by the Japanese architect and Prizker Prize recipient Shigeru Ban. Blumer-Lehmann was general contractor and timber supplier, besides providing engineering services with their sister company Creation Holz (Pfäffinge, 2013). The media company Tamedia directly commissioned the architect Shigeru Ban because they wanted a cutting-edge and sustainable building for their headquarters (Gabler, 2013). Japanese carpentry tradition is based on a high degree of accuracy, along with pure wood connections without the use of glues or steel connections. This principle was applied by Shigeru Ban in the proposed timber building, which consisted of a modern reinterpretation of Japanese joinery. The key role was played by the company Blumer-Lehmann for the construction of the digitally produced connections and joints. In 2019, the same team completed a similar project, the *Omega Headquarters*. In light of the knowledge obtained in planning the *Tamedia Office*, the team proposed a similar timber-concrete structure for two of the three buildings in the competition which they eventually won (Pfäffinge, 2013) (Jussel, 2019) (Gonchar, n.d.).

Besides these two previous projects, Blumer-Lehmann was involved in others: *Badenerstrasse* and *Mehr als Wohnen Haus J.* Built by Baugenossenschaft Zurlinden, one of the first agencies to build according to the 2000-watt requirements, *Badenerstrasse* had to be designed and built to follow the 2000-watt criteria. This led the design team to consider a timber structure. The decision for the use of wood in the construction can mainly be attributed to its valuable physical properties (Kaufmann et al., 2018). A cooperation between the owner of the building and Hermann Blumer (owner of Blumer-Lehmann) led to the newly developed Top-wall system to be used in

Badenerstrasse (Kaufmann et al., 2018). Engineering office SJB Kempter Fitze and architectural office pool Architekten were involved in the project, and both will be involved in other Swiss case-studies. In 2008 the city of Zurich launched an international architectural competition to develop the Hunziker area. *Mehr als Wohnen Haus J* was part of the twenty-six awarded projects. The goal of the competition was to design future-oriented buildings which also met sustainable targets like those of the 2000-watt society (Lignum, 2015*a*). *Mehr als Wohnen Haus J* was designed by pool Architects and built by Blumer-Lehmann.

The two hotels in the Swiss list were designed by the same architect. Carlos Martinez Architects won the architectural competition for the extension of the *Hotel Saentispark*. In order to meet the tight schedule and the ecological requirements requested by the client, it was decided to build the building with prefabricated timber elements (Lignum, 2014*a*). The five-storey building was built above the massive concrete structure in order to meet fire protection requirements (Hernández-Arcas, 2015). SJB Kempter Fitze were the timber engineers of record, and the company Blumer-Lehmann constructed and supplied the timber elements. *Hotel Revier* followed a similar path. Carlos Martinez Architects were invited to join the architectural competition for it, and they won. As they did in *Hotel Saentispark*, the architects proposed a modular timber system for the realisation of the building (Lignum, 2019*b*). The possibility of fast erection, coupled with the experience of the architects, convinced the client to build the project with timber, and three years after the completion of *Hotel Saentispark*, *Hotel Revier* was completed. Fire regulations allowed for the exposure of timber. This time, the company Kaufmann Bausysteme was involved in the construction of the project which used CLT panels supplied by Binderholz.

The company Erne successfully influenced the design of both *Suurstoffi S22* and *Arbo Suurstoffi BF1*. The two buildings are part of the same urban development led by the real estate company Zug Estate AG. Zug Estate AG organised an architectural competition for a new office building but did not specify the use of timber in the study contract (Lignum, 2020). The architectural office Burkard Meyer partnered together with the construction company Erne for the competition of *Suurstoffi S22*. Erne is a traditional construction company, but in the last years they have developed several hybrid timber-concrete systems for buildings. The team won the competition due to their hybrid design proposal, which used the Erne floor system. This system guaranteed a fast, precise and cost competitive solution, which convinced the client to go with their design (Herzog, 2018). After the success of *Suurstoffi S22*, the client Zug Estates wanted *Arbo* to be built with the same hybrid timber-concrete structure (Lignum, 2020). Erne was therefore again involved in the construction of *Arbo* after the architectural offices Büro Konstrukt - Manetsch Meyer won the architectural competition. Pirmin Jung Ingenieure and Dr.Luchniger-Meyer were both involved in the engineering of the building.

No recurrent influences were observed in the *Wohnhaus Habsburgstrasse*, *Mühlebachstrasse*, *SZU-Betrisbgebaude*, and *Asylunterkunft Rigot*. As a replacement for the existing properties, the client *Wohnhaus Habsburgstrasse* wanted a new building with flats that would meet the highest architectural and ecological requirements and require little grey energy for construction. For this reason,

the architects proposed a timber structure (Lignum, 2012). The timber engineering was made by Timbatec, a Swiss-Austrian company who also engineered *sue&til*. Hector Egger Holzbau built the project. Hector Egger Holzbau was also involved in the project *Mühlebachstrasse*. The two buildings which compose the project were commissioned directly to the architects Kämpfen für Architektur by the client. Both the client and the architect shared a common admiration for sustainable buildings (Mayo, 2015). Kämpfen für Architektur were also previously involved in sustainable architecture. *Mühlebachstrasse*, met the Minergie P-Standard, the highest energy certification in Switzerland (Lignum, 2012). The concrete building on the top of which *SZU-Betrisbgebaude* was built could not be removed. An architectural competition was organised with clear intentions to optimize the storeys being added, and needed to incorporate a light material. To meet both the targets, it was clearly necessary to build with timber (Kaufmann et al., 2018).

Asylunterkunft Rigot is an Asylum seekers residence which was commissioned by the public agency of the city of Geneva. In light of the increased amount of new asylum seekers in the country, a project which could be quickly completed was considered necessary to build a new temporary house for them (Lignum, 2019*b*). In order to be fast, the use of local materials was required. Both of these requirements led to choosing a timber structure. Because the building is temporary, the foundations are also made of timber. Several timber companies joined the project, in order to supply all the necessary materials (Lignum, 2019*b*).

Only the Japanese architect and Pritzker Prize recipient Shigeru Ban has built more than one case study in Switzerland, with two case studies having been realized. The rest of the projects have different architects. The same is the case with engineers, which are all different as well. Only Indermühle Bauingenieure has completed two case studies. As for the timber engineers, Borlini&Zanini is the only office which had two case-studies realized. All timber contractors are Swiss, except the two case-studies in the Italian region of Switzerland, where two Italian contractors got the commission. In most cases the timber used comes from Switzerland, and is assembled by Swiss companies like Renngli and Erne. Some cases had some columns and beams produced by German companies like Pollmeier and Hess Timber[12]. Implenia was the general contractor of the two biggest case studies.

[12]Hess Timber is owned by the Austrian Hasslacher Norica Timber.

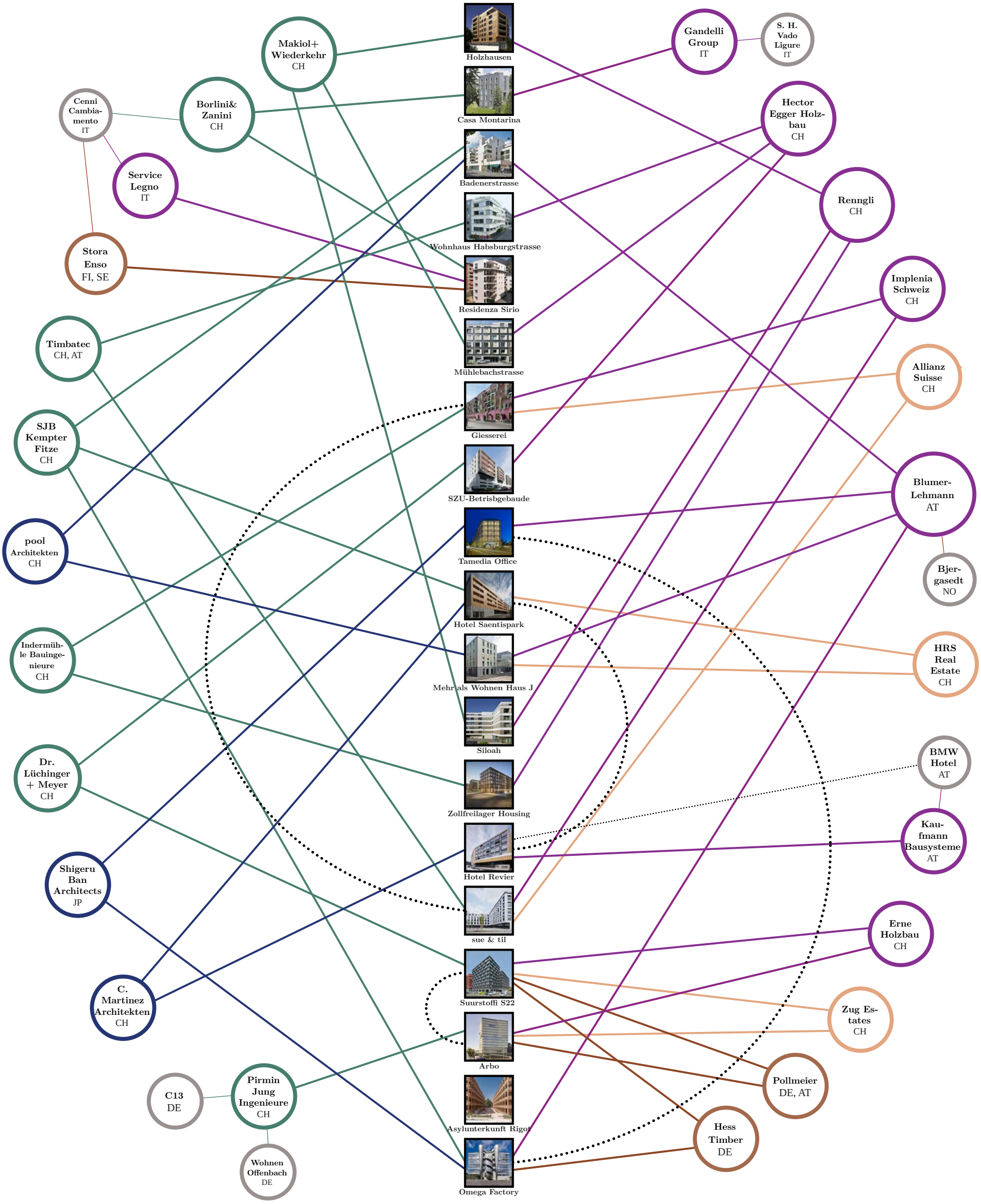

Figure 6.12: Relationships between Swiss case-studies, policies and their stakeholders

Table 6.10: List of stakeholders involved in Swiss case-studies

Project *(name)*	**Architect** *(name, country)*	**Engineer** *(name, country)*	**Timber Engineer** *(name, country)*	**General Contractor** *(name, country)*	**Timber Contractor** *(name, country)*	**Timber Supplier - Structural elements** *(name, country)*	**Timber Supplier - Floor slabs** *(name, country)*	**Client/Developer** *(name, country)*
Holzhausen	Scheitlin Syfrig Architekten, CH	Makiol-Wiederkehr, CH	Renngli, CH	Renngli, CH	Renngli, CH	Renngli, CH	Renngli, CH	Dölf und Maria Gubser Furrer, CH
Casa Montarina	Lorenzo Felder Archietetto, CH	Borlini& Zanini, CH	Borlini& Zanini, CH	Lepori - Laube, CH	Gandelli Group, IT	Stora Enso, FI, SE	Stora Enso, FI, SE	Mimi Lepori Bonetti - Lorenzo Felder, CH
Badenerstrasse	pool Architekten, CH	Henauer - Gugler, CH	SJB Kempter Fitze, CH	Caretta Weidmann, CH	Zimmereigenossenschaft Zürich, CH	Zimmereigenossenschaft Zürich, CH	Zimmereigenossenschaft Zürich, CH	Baugenossenschaft Zurlinden, CH
Wohnhaus Habsburgstrasse	Hauenstein LaRoche Schedler Architekten, CH	Urech Bärtschi Maurer, CH	Timbatec, CH, AT	Hector Egger Holzbau, CH	Hector Egger Holzbau, CH	Hector Egger Holzbau, CH	Hector Egger Holzbau, CH	Einfache Gesellschaft Osterwalder-Dahm, CH
Residenza Sirio	Ecoedil, CH	Geom. Viviani, CH	Borlini& Zanini, CH	Service Legno, IT	Service Legno, IT	Stora Enso, FI, SE	Stora Enso, FI, SE	A.Serta and J.Terzic, CH
Mühlebachstrasse	Kämpfen für architektur, CH	De Vries Engineering, CH	Makiol-Wiederkehr, CH	Hector Egger Holzbau - 1a hunkeler, CH	Hector Egger Holzbau - 1a hunkeler, CH	Hector Egger Holzbau - 1a hunkeler, CH	Hector Egger Holzbau - 1a hunkeler, CH	Monika und Muriel Kämpfen, CH
Giesserei	Galli Rudolf Architekten, CH	Indermühle Bauingenieure, CH	Indermühle Bauingenieure, CH	Implenia Schweiz, CH	Knecht, Implenia Bau - Brunner Erben, CH	Knecht - Implenia Bau - Brunner Erben, CH	Knecht - Implenia Bau - Brunner Erben, CH	Gesewo - Allianz Suisse, CH
SZU-Betrisbgebaude	Burkhalter Sumi Architekten, CH	Dr.Lüchinger - Meyer, CH	Hector Egger Holzbau, CH	Unirenova, CH	Hector Egger Holzbau, CH	Hector Egger Holzbau, CH	Hector Egger Holzbau, CH	SZU, CH
Tamedia Office	Shigeru Ban Architects, JP	Creation Holz, CH	Creation Holz, CH	HRS Real Estate, CH	Blumer-Lehmann, CH	Blumer-Lehmann, CH	Blumer-Lehmann, CH	Tamedia, CH
Hotel Saentispark	Carlos Martinez Architekten, CH	Naenny - Partner, CH	SJB Kempter Fitze, CH	HRS Real Estate - HRS Renovationen, CH	Blumer-Lehmann, CH	Blumer-Lehmann, CH	Blumer-Lehmann, CH	HRS Real Estate, CH
Mehr als Wohnen Haus J	pool Architekten - Futurafrosch, CH	Edy Toscano - Ernst Basler-Partner, CH	Blumer-Lehmann, CH	Sohm, CH	Sohm, CH	Sohm, CH	Sohm, CH	Baugenoschennschaft Mehr als Wohnen, CH
Siloah	Andreas Garraux Architekt, CH	Emch - Berger - Makiol Wiederkehr - Grünig & Partner, CH	Emch - Berger - Makiol Wiederkehr - Grünig & Partner, CH	Renngli, CH	Renngli, CH	Renngli, CH	Renngli, CH	Stiftung Siloah, CH
Zollfreilager Housing	Rolf Mühlethaler Architekt, CH	Adamina Zeerleder Partner - MPAG Marchand-Partner, CH	Indermühle Bauingenieure, CH	Allreal Generalunternehmung, CH	Renngli, CH	Renngli, CH	Renngli, CH	Zürcher Freilager, CH
Hotel Revier	Carlos Martinez Architekten, CH	Plan 4, CH	Josef Kolb, CH	Baukla generalunternehmung, CH	Kaufmann Bausysteme, AT	Binderholz, AT	Binderholz, AT	Fortimo Invest, CH
sue & til	Weberbrunner Architekten - Soppelsa Architekten, CH	Dr. J.Grob & Partner, CH	Timbatec, CH, AT	Implenia Schweiz, CH	Implenia Schweiz, CH	Implenia Schweiz, CH	Implenia Schweiz, CH	Allianz Suisse, CH
Suurstoffi S22	Burkard Meyer Architekten, CH	MWV Ingenieure, CH	Erne Holzbau, CH	Erne Holzbau, CH	Erne Holzbau, CH	Hess Timber, DE	Pollmeier, DE	Zug Estates, CH
Arbo	Büro Konstrukt - Manetsch Meyer, CH	Dr.Luchniger-Meyer, CH	Pirmin Jung Ingenieure, CH - TiComTec, DE	Archobau, CH	Erne Holzbau, CH	Pollmeier, DE	Pollmeier, DE	Zug Estates, CH
Asylunterkunft Rigot	Acau Architecture, CH	T-ingéniére - Thomas Jundt, CH	Charpente Concept, JDP-Ducret, CH	Enterprise Générale - JPF Construction, CH	JDF-Ducret SA - Dasta Charpente Bois SA - Casai SA, CH	Desponds - Bulle - Zahnd - Burgat - A-C Corbat, CH	Desponds - Bulle - Zahnd - Burgat - A-C Corbat, CH	Hospice général - Service immobilier - Les Acacias, CH
Omega Headquarters	Shigeru Ban Architects, JP	SJB Kempter Fitze, CH	SJB Kempter Fitze - Design-to-Production, CH	Blumer-Lehmann, CH	Blumer-Lehmann, CH	Hess Timber, DE	Blumer-Lehmann - Lehmann Holzwerk, CH	Hayek family, CH

6.3.11 United Kingdom

see Appendix pages 456-478

Behind the twenty-three British case-studies there were mainly two recurring stakeholders involved: Waugh Thistleton Architects and Eurban. Waugh Thistleton Architects realized seven case studies, whereas nearly half of the projects (twelve case-studies) were engineered and built by Eurban. The company offers both engineering consulting and also works to help erect the timber structure. Another relevant driver was the council of Hackney. The majority of the case-studies are located in the North-East area of the inner City of London, in the Hackney district. After the success of *Stadhaus*, the council of Hackney began implementing favourable policies towards timber. The Council represents an example of how a favourable public player can turn a district into one of the densest area for MTB's on the planet.

In 2006, the UK Government began a campaign called "Wood for Good" with the goal of increasing the use of timber in all industries related to construction (Anttonen, 2015). In parallel, already in 2007 a first network of professionals was formed in London with several offices like Eurban, Techniker, dRMM, Quay2C, and PRS Architecture, which began to build the first CLT projects in the country. Since 2005, KLH UK (the sister company of the Austrian manufacturer) started to supply CLT to the English market (Fourthdoor, n.d.*c*). Prior to this, the Timber Frame 2000 project (TF2000) was created in order to research the technical issues of MTBs with a panelised structural system. The result of the project led to the decrease in fire restrictions in the UK. This project, together with the removal height limits for MTBs, created the necessary environment for all the case-studies to occur (Green and Karsh, 2012).

The first case-study of the UK is *Fairmule House*, completed in 2006. The architect got a private commission and considered the possibility to realise the building with timber due to sustainability goals. Eurban was consulted to propose an alternative structural system and the building was approved to be built in CLT (New Civil Engineer, 2005). KLH was the timber supplier, making *Fairmule House* the first project supplied by the Austrian company in the UK (Fourthdoor, n.d.*c*). The ceilings were left exposed throughout the apartments, a key requirement of the design.

After this first experience, KLH realised the highest MTB in the UK in 2009, and in the world at that time. *Stadthaus* was the building which triggered the UK's interest in building timber projects in an urban context (Fourthdoor, n.d.*c*). The building was officially opened in 2009, and was finished at the end of 2008. It stands in Hackney, in the same quarter of *Fairmule House*. *Stadthaus* was designed by Waugh Thistleton Architects and Technicker. Being the first building of its type, the building needed extra documentation for the authority and additional acoustic tests were founded by KLH (Wiegand, 2019). Architect and CLT-Manufacturer KLH (represented by Karl Heinz Weiss), formed a professional allyship in order to get the project realized, referring to the European Technical Approval (ETA) to meet the code for fire, structural and thermal requirements (Wiegand, 2019). *Stadthaus* can be considered the building that started the second generation of MTBs. Because it was the first high-rise MTB at the time, it immediately got the

attention of national and international players. To put it in perspective, it was only ten years ago that CLT was beginning to be developed (Fourthdoor, n.d.*b*). Until *Stadthaus*, MTBs were merely a niche branch of construction but with this project, the industry proved that the return of timber to the city was feasible. The project also became the reason for the travels of many international delegations of experts, governmental offices and policymakers (Fourthdoor, n.d.*c*).

After the success of *Stadthaus*, Waugh Thistleton Architects designed other mass timber projects, including the case-studies *Whitmore Road*, *Curtain Place*, *106 Lewes Road*, *55 Pitfield Street*, *Woodberry Down*, *Dalston Lane*, *55 Pitfield Street*, and *Green House*. *Whitmore Road* was built because the three owners agreed on building the project with timber. One of which was the partner of Waugh Thistleton (Fourthdoor, n.d.*c*). *Curtain Place* plot has a narrow entrance which created some challenges for the delivery of a traditional construction. For this reason a hybrid steel and CLT structure was designed by the architects (Waugh Thistleton Architects, n.d.). *106 Lewes Road* represented an innovation for Waugh and Thistleton Architects. Instead of using only CLT, the office designed the building with the majority of the walls made of pre-assembled timber panels produced in Austria (Fourthdoor, n.d.*d*). *Woodberry Down* is part of a large multi-function redevelopment by the Berkeley Group. The design team wanted to design this small project, with the goal to prove the clear constructive benefits of using CLT in order to influence the future projects in the area (Eurban, n.d.*e*). *55 Pitfield Street* is a passive house building which was able to achieve this status thanks to its CLT structure (Waugh Thistleton Architects, 2018). The *Green House* project is a refurbishing of an existing concrete building with an extension formed by CLT panels (Tower Hamlets, n.d.). The reason that compelled *Dalston Lane* to have a timber structure was due to the building site. Because the building is on top of an underground line, it could not be too heavy due to the limitations of the foundational depth (Da Col, 2017). Additionally, thanks to its timber structure, the architects were able to design more flats with this space.

Based on *Stadthaus* success, the city council of Hackney decided to promote timber more intensively. In 2012, the Council launched the "Timber First" policy, an Information tool, whose goal was to support the use of timber over other building materials (Wiegand, 2019). Thanks to this policy, Hackney became the epicentre of MTBs in the years following, competing with other cities like the Växjö and Vienna. *Birdport House* was built thanks to the properties of timber. Having a Victorian storm sewer running directly beneath the building site, the new building had to be as light as possible, due to the limit of the foundation depth (Green and Taggart, 2017). The architect of *Nordic Lofts* convinced the developer to adopt his idea of a CLT building. It was the architect's opinion that using CLT would have made the project look better and also save money, thanks to the quick construction time of CLT panels. The architect turned out to be right, both saving the developer's money and winning several architectural prizes (Manon Mollard, 2016). *Wenlock Road 17-21* was proposed by the design team with a timber structure (Smith, 2014) (Green and Taggart, 2017). As with many other case-studies, this building is situated in the London Borough of Hackney. Hawkins Brown had previous experience in working with CLT having recently completed a large school building with it. As a direct result, they talked early on with the planners about

the possibility of building the scheme in CLT. The scheme at *Wenlock Road 17-21* was awarded with the planning phase in 2012. One of the conditions of the approval was that the scheme must be constructed in CLT - which was unusual at the time (Smith, 2014).

Both *Cobalt Place* and *Trafalgar Place* were developed by Lendlease. Lendlease commissioned Walsh Associates to identify the proper structure for the construction of *Cobalt Place* (Walsh Associates, n.d.). The engineering office proposed both concrete and CLT, but CLT was favoured by the client, who then commissioned Eurban to build it. The architectural office dRMM of the project *Trafalgar Place* was amongst the first in the UK to use CLT. In coordination with Eurban and Lendlease, the office specified CLT in the design of the building (dRMM, n.d.).

Other projects were completed in London, mainly engineered and constructed by Eurban. The *Kingsgate House* integrates several sustainable strategies which also made it one of the first certified PEFC projects (Waugh Thistleton Architects, 2018). The owner wanted to build a project in which the local people could live in the area with affordable rent and high standards of living (Willmott Dixon, n.d.). *Bacton Low Rise* benefited from the London Borough of Camden's Community Investment Programme, which managed governmental funding for developing the area in which the building is located. The project is part of a flagship development including both private and social housing flats. Karakusevic Carson Architects (which designed *Birdport House*) were in charge of the area's masterplan, and they specified that the buildings needed to utilise sustainable materials (Karakusevic Carson Architects, n.d.). CLT was championed in this development and the architects ended up designing one of the buildings. The building *Highpoint Terrace* is part of an urban development which includes a 47-storey concrete building (Highpoint Tower). *Highpoint Terrace* was originally conceived as a precast concrete frame, but a timber approach was considered thanks to Eurban, who proposed CLT. Logistics of the simultaneous delivery of the two buildings on the tight urban site made the conceptualisation of the structure with CLT, *"the most efficient solution in terms of cost, speed, health and safety"* (Eurban, n.d.*b*). The original design of *Press House* was conceived with a traditional structure. The idea of building it with CLT came later and was a specific request of the client (Geraghty, 2020). The redesign of the project was possible and in the end, the building was built with CLT panels engineered and built by Eurban. However, the design team faced several challenges in re-arranging the design in order to make it work with CLT, which shows that a building should be considered built with timber from the very beginning. Stride Treglown and Eurban worked together to develop the sustainable concept made by Studio Egret West for the *Boiler House*. The design team came up with a CLT building structure which guaranteed quality and speed of assembly of the project (Stride Treglown, n.d.).

UEA Crome Court, *UEA Blackdale*, *Ellerslie Road*, and *106 Lewes Road* (previously described) were realised outside of London. A strict time schedule, the need to reduce noise and attention to sustainable solutions led the public client, the University of Northumbria to realise that a CLT structure was the proper solution for *UEA Crome Court* (Ramboll, n.d.). The student housing needed to be ready before the beginning of the semester and was even built ahead of time and with a shorter budget. In light of this successful design accomplishment, *UEA Blackdale* was designed

by the same architects who worked on *UEA Crome Court* (LSI Architects) which replicated their design know-how on this second project (Waugh Thistleton Architects, 2018). The location of *Hands Building* brought some logistic issues out, which needed to be solved by the contractors. The site's tight urban and historic context of the University of Oxford, restricted delivery access and required low noise emission because it was on campus. CLT turned out to be the proper material for the project after the concrete podium was completed (MICA Architects, n.d.). Eurban was also involved in this project and planned a 4D BIM coordination delivery, merging the advantages of CLT with the potential of BIM (Eurban, n.d.*d*). The last case-study described is *Ellerslie Road*, the only Scottish project. This project was funded by Glasgow City Council. The building passed the Building Warrant approval after the submission of evidence to Scottish Building Standards Division, Glasgow City Council and Scottish Fire and Rescue Services. The owner CCG actively researched and tested the use of CLT for many years with assistance from Edinburgh Napier University (Mast Architects, n.d.).

Beside the previously mentioned Waugh Thistleton Architects and Eurban, other players were involved in several case-studies like the engineering office Ramboll (three case-studies), Karakusevic Carson Architects, LSI Architects, and contractor Price & Myers. They were all involved in two case-studies each. Regarding the general contractors, several companies were involved twice. On the timber contractor side, Eurban B&K Structures and KLH were the three companies behind the vast majority of case-studies. One case-study was built by Ecore Construction and the contractor of one was not found. No timber supplier of the selected case-studies is from the United Kingdom. All EWPs were produced in Austria by Austrian manufactures or by Stora Enso, except the project supplied by the Basque company Egoin.

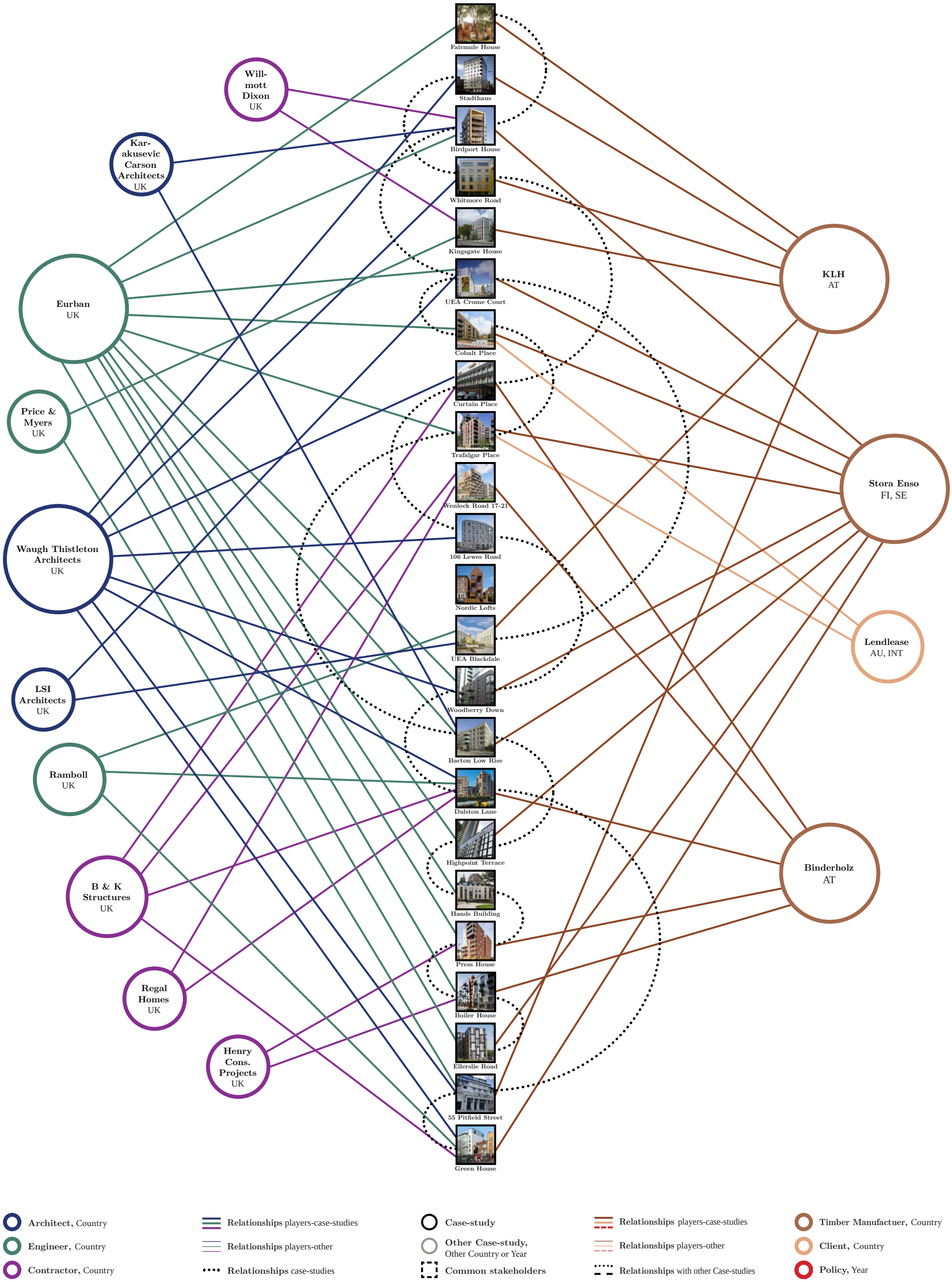

Figure 6.13: Relationships between British case-studies, policies and their stakeholders

Table 6.11: List of stakeholders involved in British case-studies

Project *(name)*	**Architect** *(name, country)*	**Engineer** *(name, country)*	**Timber Engineer** *(name, country)*	**General Contractor** *(name, country)*	**Timber Contractor** *(name, country)*	**Timber Supplier - Structural elements** *(name, country)*	**Timber Supplier - Floor slabs** *(name, country)*	**Client/Developer** *(name, country)*
Fairmule House	Quay 2c, GB	Anders Associates, GB	Eurban, GB	L I Construction, GB	Eurban, GB	KLH, AT	KLH, AT	Lint Group, GB
Stadthaus	Waugh Thistleton Architects, GB	Techniker, GB	Techniker, GB - KLH, AT	Telford Homes, GB	KLH, AT	KLH, AT	KLH, AT	Telford Homes, GB
Birdport House	Karakusevic Carson Architects, GB	Peter Bret Associates, GB	Eurban, GB	Willmott Dixon, GB	Eurban, GB	Stora Enso, FI, SE	Stora Enso, FI, SE	London Borough of Hackney, GB
Whitmore Road	Waugh Thistleton Architects, GB	Akera Engineers, GB	KLH, AT	Jerram Falkus Construction, GB	KLH, AT	KLH, AT	KLH, AT	Withheld, GB
Kingsgate House	Horden Cherry Lee Architects, GB	Price & Myers, GB	KLH, AT	Willmott Dixon, GB	KLH, AT	KLH, AT	KLH, AT	Lancer Assett Management, GB
UEA Crome Court	LSI Architects, GB	Eurban, GB	Eurban, GB	Keir Construction, GB	Eurban, GB	Stora Enso, FI, SE	Stora Enso, FI, SE	University East Anglia, GB
Cobalt Place	AHMM Architects, GB	Walsh Associates, GB	Eurban, GB	Lendlease, INT	Eurban, GB	Stora Enso, FI, SE	Stora Enso, FI, SE	Lendlease, INT
Curtain Place	Waugh Thistleton Architects, GB	Richard Jackson Engineering, GB	B & K Structures - Engenuiti, GB	Gold Section Homes, GB	B & K Structures, GB	Binderholz, AT	Binderholz, AT	Gold Section Homes, GB
Trafalgar Place	dRMM Architects, GB	Robert Bird group, GB	Eurban, GB	Lendlease, INT	Eurban, GB	Stora Enso, FI, SE	Stora Enso, FI, SE	Lendlease, INT
Wenlock Road 17-21	Hawkins Brown Architects, GB	Pringuer James Engineers, GB	Pringuer James Engineers, GB	Regal Homes, GB	B & K Structures, GB	Binderholz, AT	Binderholz, AT	Eurobuild Properties, GB
106 Lewes Road	Waugh Thistleton Architects, GB	n/a	n/a	n/a	n/a	Austria	Austria	McLaren, GB
Nordic Lofts	Amin Taha Architects - Groupwork, GB	Webb Yates Engineers, GB	Ecore Construction, GB	Ecore Construction, GB	Ecore Construction, GB	Egoin, ES	Egoin, ES	Cobstar Development, GB
UEA Blackdale	LSI Architects, GB	Ramboll, GB	Ramboll, GB	RG Carter, GB	KLH, AT	KLH, AT	KLH, AT	University East Anglia, GB
Woodberry Down	Waugh Thistleton Architects, GB	Eurban, GB	Eurban, GB	Berkeley Homes, GB	Eurban, GB	Stora Enso, FI, SE	Stora Enso, FI, SE	Berkeley Homes, GB
Bacton Low Rise	Karakusevic Carson Architects, GB	Roltons, GB	Eurban, GB	Rydon, GB	Eurban, GB	Stora Enso, FI, SE	Stora Enso, FI, SE	Camden Council, GB
Dalston Lane	Waugh Thistleton Architects, GB	PJCE, GB	Ramboll, GB	Regal Homes, GB	B & K Structures, GB	Binderholz, AT	Binderholz, AT	Regal London, GB
Highpoint Terrace	Rogers Stirk Harbour and Partners - Axis Architects, GB	n/a	Eurban, GB	n/a	Eurban, GB	Stora Enso, FI, SE	Stora Enso, FI, SE	MACE - Peabody House Association, GB
Hands Building	MICA Architects, GB	Eckersley O'Callaghan, GB	Eurban, GB	Beard Construction, GB	Eurban, GB	n/a	n/a	Mansfield College Developments, GB
Press House	Geraghty Taylor, GB	Eurban, GB	Eurban, GB	Henry Construction Projects, GB	Eurban, GB	Binderholz, AT	Binderholz, AT	Network Homes, GB
Boiler House	Stride Treglown, GB	Eurban, GB	Eurban, GB	Henry Construction Projects, GB	Eurban, GB	Binderholz, AT	Binderholz, AT	HUB - Realstar, GB
Ellerslie Road	Mast Architects, GB	Smith and Wallwork Engineers, GB	Eurban, GB	Sanctuary Scotland, GB	Eurban, GB	Stora Enso, FI, SE	Stora Enso, FI, SE	CCG, GB
Pitfield Street	Waugh Thistleton Architects, GB	Elliott Wood, GB	Pryce & Myers - KLH, GB	Simply Construct, GB	KLH, AT	KLH, AT	KLH, AT	Garfwish, GB
Green House	Waugh Thistleton Architects, GB	Ramboll, GB	Ramboll, GB	n/a	B & K Structures, GB	Stora Enso, FI, SE	Stora Enso, FI, SE	Etichal Property, GB

6.3.12 Canada

see Appendix pages 480-489

The Canadian case-studies can be divided in two different areas: one focuses on the case-studies in the British Columbia, the other the case-studies in Quebec. Since October 2009, all Canadian newly constructed publicly funded buildings such as schools, libraries or sports complexes, must consider timber as primary building material (MakeitWood, 2018). The National Building Code was updated in order to allow timber-based buildings up to six storeys tall. Additionally, higher buildings can be considered under "Site Specific Regulations" (SSR) if the design team demonstrate the compliance by performance criteria (Wiegand, 2019).

In British Columbia, the majority of the buildings were commissioned by a public university as an investor: four case-studies had a public Canadian university as investor and all of them received government founds (Wiegand, 2019). The Wood First Act released in 2009 in British Columbia influenced in particular educational-related projects. The policy gave support to designers by facilitating the share of know-how and elaborated regulatory framework for the commissioned buildings (Wiegand, 2019). In this context the University of British Columbia (UBC), according to an interview reported in Wiegand (2019) *"carried out more than twenty mass timber projects"*. The first building which took advantage of the Wood First Act was the educational building *UBC Earth Sciences*, completed in 2012. UBC, needed a new Earth Science program department. The choice of timber was considered in the positive connection between the program department (Earth Sciences) and the natural material (timber). In the design phase, the main goal became the reduction of the carbon emissions and the target LEED Gold: using timber became in-line with the target of the client (Woodworks, 2012). Even if at the beginning CLT was considered as floor system, lack of availability and competitive solutions represented by LSL-concrete floor slabs, made the design team to opt for the latter. Before 2011, no CLT manufacturer was available in Canada and therefore the projects built before these years could only use other EWPs products like glulam or import it from Europe. The building was designed by the international office Perkins+Will, which also published a survey of mass timber buildings, commented in the literature review (Holt and Wardle, 2014). The timber engineer of record was the office Equilibrium. As the other frequent engineering office Fast+Epp, Equilibrium had a long experience with timber construction. Erick Karsh, one of the partners of the office, published together with architect Michael Green, a publication on possible concepts for tall wood buildings Green and Karsh (2012). Both Michael Green and Equilibrium were acquired by the American construction company Katerra in 2018 (Keane and Lau, 2018). Equilibirum and Michael Green Architects planned the educational building *Wood Innovation Centre* for the Province of British Columbia. The building was designed higher than the maximum height prescribed by the regulatory framework. Thanks to the SSR specification in Wood First Act, the building obtained the necessary permissions and became a legal precedent (Wiegand, 2019). *Wood Innovation Centre* is also the first building using CLT in Canada in such tall construction, and it was designed to trigger interest in this new timber product. In 2011, with funding support from the provincial government, Structurlam opened North America's first CLT and supplied the

necessary EWPs for *Wood Innovation Centre* (Church, 2019).

Five years later the UBC commissioned *UBC Brock Commons*, which was the tallest building in the world from 2017 (year of its completion) until 2019 (Kaufmann et al., 2018). *UBC Brock Commons* was designed and built thanks to the "Tall Wood Building Demonstration Initiative" (TWBDI) which was a governmental program lunched by *"National Resource Canada (NRCan) in collaboration with Canadian Wood Council and the Binational Softwood Lumber Council, Forestry Innovation Investment and the British Columbia Provincial, amongst other institutions"* (Wiegand, 2019). As with the other project, Structurlam provided the EWPs and the engineering office Fast+Epp was the engineer of record. The architects of record of this project was Acton Ostry Architects with the Austrian Architect Hermann Kaufmann involved in the project as consultant. The team performed several fire, moisture and durability tests and other internal testing.

Lakeside Resort Expansion is the only privately founded project on the West coast of Canada. Timber was chosen thanks to the Penticton Lakeside Resort's managing group which wanted to use a sustainable material for the expansion of the existing resort (Arstad, 2016) With this project included, all these case-studies were supplied by Structurlam which also supplied three projects in the United States. The only project which had its timber elements sourced from Austria was *Wilson School of Design* (Jones, 2018). Fast+Epp was involved in the realisation of the building, as Seagate Structures, the same company which built *UBC Brock Commons*. The project was founded by three players: a third of the cost came from the British Columbia Government and another third came by Kwantlen Polytechnic University. The entrepreneurs Shannon and Chip Wilson donated the last third.

If in British Columbia, the majority of the projects were publicly funded, in Quebec only private investors financed the realisation of the case-studies. However, also the province of Quebec passed several measures for the promotion of timber in the region, like the program "Wood Use Strategy for Construction". *CSN-Fondaction* project was allowed thanks to the early modification of the Building Code in 2009. CSN-Fondaction needed a new building and found a plot. The initial desire was to build a sustainable building with LEED certification but with a traditional structure. Only afterward did the idea of a timber structure begun to emerge in the decision process, both for the many possibilities offered this material under construction and as a gesture of support for workers and the Quebec forest economy (Cecobois, 2011). The design team applied and got the building permissions. It was the first time that the local authority (Régie du bâtiment) authorized the erection of a non-residential timber building of more than four storeys. The timber engineer of record and the timber manufacturer was Nordic Structures, a timber manufacturer established in the Chibougamau (Quebec) which supplied all the Quebec case-studies (and also two in the United States). The private client of *Synergia* selected timber as a principal material for its environmental, aesthetic and health benefit properties. The design of the office integrates several sustainable strategies and technologies. The project was built by FGP Construction, which will be involved in two other projects.

Before realising *District 03* in 2013, the year before Nordic Structures completed a four-storey project named *Habitation Nordic*, which has a similar panelised system. *District 03* was initially planned with a concrete structure. But an analysis suggested that the soil could not support the load without a major pumping operation. This convinced the developer to change his plans and to use the timber (Cecobois, 2015). A timber structure did not require a stake for the foundations. Even if a second analysis found that the bearing capacity of the soil was sufficient to support a concrete building, the people who had already bought their condo had so welcomed the change for timber, that the decision was upheld (Cecobois, 2015). Also in this case, the material change was made possible by adjustments between the project engineers and the Régie du bâtiment du Québec (RBQ). Lemay, Nordic Structures and FGP Construction were behind the design of *District 03* and also of *Arbora*, the largest Canadian CLT project by the end of 2019. Certified LEED Platinum, *Arbora* was commissioned by a developer which wanted to build an innovative and sustainable real estate development. As for *District 03*, the light properties of timber structures were the reason for the choice of CLT in *Origine Condos*. The tall residential project would not have been possible to build with other structural materials due to the soil conditions of the plot. The site is near a river, and it had a very poor load-bearing capacity (Dovetail, 2020). In order to build the project, the design team conducted two years of research, including seismic and full-scale fire testing, to ensure optimal structural resilience and safety.

Figure 6.14 shows the highly interconnected relationships between the Canadian case-studies. If the architects in British Columbia were all different, Lamay planned three of the five Quebec project. Timber engineers of record in British Columbia were mainly Equilibirum and Fast+Epp, whereas in all the Quebec projects Nordic Structures resulted as timber engineer of record. Fast+Epp founded the EWPs manufacturer StructureCraft. The company did not supply any Canadian case-studies, but supplied several from the United States. In this regard, many Canadian players were involved in projects in the United States. The Canadian-United States know-how exchange is a particular one from the overall perspective observed in this dissertation. These connections took place mainly between the Canadian British Columbia and the American states of Washington and Oregon.

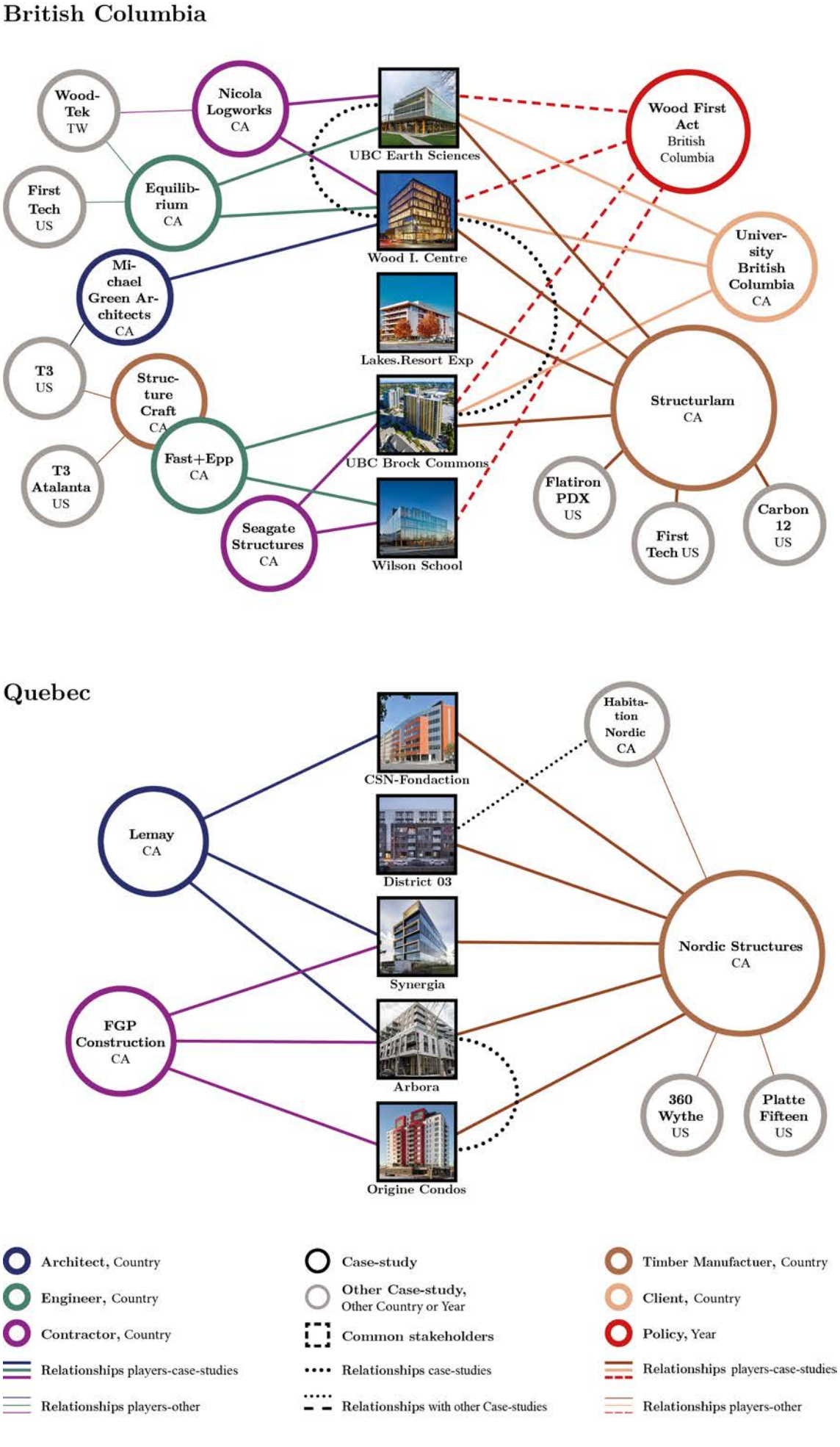

Figure 6.14: Relationships between Canadian case-studies, policies and their stakeholders

Table 6.12: List of stakeholders involved in Canadian case-studies

Project *(name)*	**Architect** *(name, country)*	**Engineer** *(name, country)*	**Timber Engineer** *(name, country)*	**General Contractor** *(name, country)*	**Timber Contractor** *(name, country)*	**Timber Supplier - Structural elements** *(name, country)*	**Timber Supplier - Floor slabs** *(name, country)*	**Client/Developer** *(name, country)*
CSN-Fondaction	Gilles Huot - GHA Atelier d'architecture, CA	Bureau d'Études Spécialisées, CA	Nordic Structures, CA	Pomerlau, CA	Nordic Structures, CA	Nordic Structures, CA	Nordic Structures, CA	CSN-Fondaction
UBC Earth Sciences	Perkins + Will, US, CA	Equilibrium, CA	Equilibrium, CA - TiComTec, DE	Bird Construction, CA	Adera Construction - Nicola Logworks, CA	Structurlam, CA	Structurlam, CA	University of British Columbia, CA
District 03	Lemay, CA	n/a	Nordic Structures, CA	n/a	Nordic Structures, CA	Nordic Structures, CA	Nordic Structures, CA	n/a
Wood Innovation Centre	Michael Green Architects, CA	Equilibrium, CA	Equilibrium, CA	PCL Constructors Westcoast, CA	Nicola Logworks, CA	Structurlam, CA	Structurlam, CA	Province of British Columbia, CA
Synergia	Lemay, CA	n/a	Nordic Structures, CA	n/a	FGP Construction, CA	Nordic Structures, CA	Nordic Structures, CA	Robin group, CA
Arbora	Lemay - CHA, CA	n/a	Nordic Structures, CA	Sotramont, CA	FGP Construction, CA	Nordic Structures, CA	Nordic Structures, CA	Sotramont, CA
Lakeside Resort Expansion	Nick Bevanda Architects, CA	RJC Consulting Engineers, CA	Structurlam, CA	Greyback Construction, CA	n/a	Structurlam, CA	Structurlam, CA	RPB Hotels, CA
Origine Condos	Yvan Blouin Architecture, CA	WSP - Génécor, CA	Nordic Structures, CA	EBC, CA	FGP Construction, CA	Nordic Structures, CA	Nordic Structures, CA	NEB Group, CA
UBC Brock Commons	Acton Ostry Architects, CA - Hermann Kaufmann, AT	FAST - EPP, CA	FAST - EPP, CA	Urban One Builders, CA	Seagate Structures, CA	Structurlam, CA	Structurlam, CA	University of British Columbia, CA
Wilson School of Design	KPMB Architects - Public Architecture, CA	Core Group, CA	FAST - EPP, CA	DGS Construction, CA.	Seagate Structures, CA	Binderholz, AT	Binderholz, AT	Kwantlen Polytechnic University, CA

6.3.13 United States of America

see Appendix pages 491-504

All the American case-studies have a private investor with the only exception being *Adohi Hall* promoted by the University of Arkansas. Furthermore, the majority of the projects were realised thanks to the wish of the private client to build a sustainable building, as headquarter or offices.

The Bullitt Foundation decided to built its new building house, the *Bullitt Center*, with the goal to build one of the most sustainable building in the world (Green and Taggart, 2017). The choice of the structure was initially concrete thanks to its thermal mass. However, being the goal of the project to reach a net zero target certification, timber was the only option according to a Life Cycle Analysis comparison between several construction materials (Green and Taggart, 2017). In order to meet the certification targets, the structural timber had to be sourced from nearby timber manufacturers. A tour of the *Bullitt Center* inspired architect and entrepreneur Ben Keiser to pursue the mass timber construction in Portland. He privately developed his first project *Radiator* through his companies Keiser Group and the architectural office PATH Architecture (Libby, 2015). In 2014 Keiser Group applied for the US Tall Wood Building Prize Competition. The competition aimed to promote innovative MTBs designs by offering a grant to the two best proposals. The project turned out to be *Carbon 12*, was not awarded by the jury, but Keiser Group decided to build the project anyway (BuildingCarbon12, 2020). The company begun to research the plot. Additionally, the city of Portland was favourable to the project and relaxed the height limits for timber building in order to allow the construction of the eight-storey building. Munzing Structural Engineers were involved in both the projects and the CLT floor slabs were supplied by the Canadian Structurlam.

Work Progress Architecture designed both *Framework* and *Flatiron PDX*. In *Framework*, both the architectural office and the client agreed to reinterpret the architecture of the historic timber frame industrial structure of Portland and pursued a timber structure (Brake, 2015). At the same time the city of Portland was particularly pushing for sustainable buildings and allowed timber projects of five-storey. The CLT floors were used in *Flatiron PDX* for their unique ability to simplify the corner geometries structural requirements. Thanks to the two-directional strength behaviour of CLT panels, the design team was able to use the material to create the laced corners with double cantilever balconies (Structurlam, 2020*b*).

Both *T3* and *T3 Atlanta* were developed by the same private investor Hines (StructureCraft, n.d.). *T3* fully exploits the maximum height allowed by the State of Minnesota for timber buildings. The building was designed by Michael Green architects which designed previously the *Wood Innovation Centre* in Canada. No special permit was required, but a sprinkler system had to be installed, as the interior wood surfaces have been left exposed to view (Green and Taggart, 2017). The Canadian StructureCraft supplied the EWPs for the structure. In light of the success of *T3*, three years later *T3 Atlanta* was completed. The project is similar to *T3* but this time StructureCraft supplied DLT instead of NLT (StructureCraft, n.d.).

Other four case-studies *38 Davis*, *Clay Creative*, *First Tech Federal Credit Union*, and *Sideyard* were completed in Portland (or near it), all thanks to the wish of the client. *38 Davis* was one of the first LEED New Construction v4 building completed in Portland. The architect of record Ankrom Moisan Architects designed *38 Davis* in order to create a representative office space in which they relocate. In order to reinterpret the Portland timber culture, the design team came up with the timber structure which allowed the building to meet the high sustainable targets set by the client (Ankrom Moisan Architects, 2016). The developer of *Clay Creative* got the permission to renovate an area of Portland where a former warehouse was destroyed by a fire. Afterwards the area became part of the street culture of the city. Also in this case the design team reinterpreted the historical warehouse context, designing a timber structure. The owner had the goal to develop a LEED office in which he relocated its headquarter and was in favour of the timber structure (Kramer-Gehlen, 2020) (Killian Pacific, n.d.). *First Tech Federal Credit Union* is the headquarter of a company with the same name, which had the goal to have an innovative and environmental friendly new office (Structurlam, 2020*a*). For this reason the company commissioned Hacker architects to design with the highest sustainable standards and was open to innovative solutions proposed by the architects, including having a timber structure to meet the highest sustainability certification possible. As for other projects, two Canadian players were involved: Equilibirium and Structurlam. *Sideyard* was built by Andersen Construction, which was also involved in the construction of *38 Davis*. The developer of the project recognized the potential of a residual plot of a recent urban development, which was considered of no value to the city. The developer then formed a design team and proposed an urban project which connects the two side of the area with a stair. Since the beginning, the idea was to develop the building with a CLT-based structure (Think Wood, n.d.*c*). CLT floors were supplied by the nearby DR Johnson and made easier the construction of the building which is located in a narrow access.

All the remaining three projects were supplied by foreign timber suppliers: *360 Wythe* and *Platte Fifteen* by the Canadian Nordic Structures (and built by FGP Construction), *Adohi Hall* by the Austrian Binderholz. After other attempts by the developer to get permission to build the first MTBs in New York in decades, he understood that it was easier to get the approval by the authority with a lower, mid-rise building (Nonko, 2018). *360 Wythe* was therefore designed and got the approval of construction. At the time of the project, the city rules allowed timber buildings up to six stories (Nonko, 2018). The design of *Platte Fifteen* is the result of the positive collaboration of the architectural office OZ Architecture, with the developer Crescent. Both had the goal to design a sustainable building, and they collaborated on a previous CLT project in 2017 (Oppermann-Stern, 2018). Focused on sustainable development, Crescent wanted to design a mass timber project in order to achieve high LEED certifications for its building.

Finally, *Adohi Hall* is the only project developed by a public player. The area's long history as a heavily forested region motivated the architects and the university to pursue this ambitious mass timber project (ArchDaily, n.d.*a*). The architects of *Adohi Hall* also realized the *Umass building* a four-storey timber project which was the first educational project in the US using CLT (ArchDaily,

n.d.*c*).

By the analysis of the stakeholders, architects are heterogeneous, and only two architectural offices repeat in the list (PATH Architects and Work Progress Architecture). The Canadian Michael Green designed the *T3* building for Hines and other offices like OZ Architecture had experience in smaller buildings. Engineering offices are slightly less heterogeneous as DCI Engineers were involved in three case-studies, Kramer Gehelen&Associates and Magnusson Klemencic Associates were involved in two case-studies each. Regarding the timber suppliers, half of the case-studies are built with foreign EWPs coming mainly from Canada and with two case-studies using EWPs from Austria. Structurlam supplied three case-studies. Nordic Structures and StructureCraft supplied two case-studies each. Keiser Group which owns PATH Architecture, developed two case-studies as Andersen Construction and Hines.

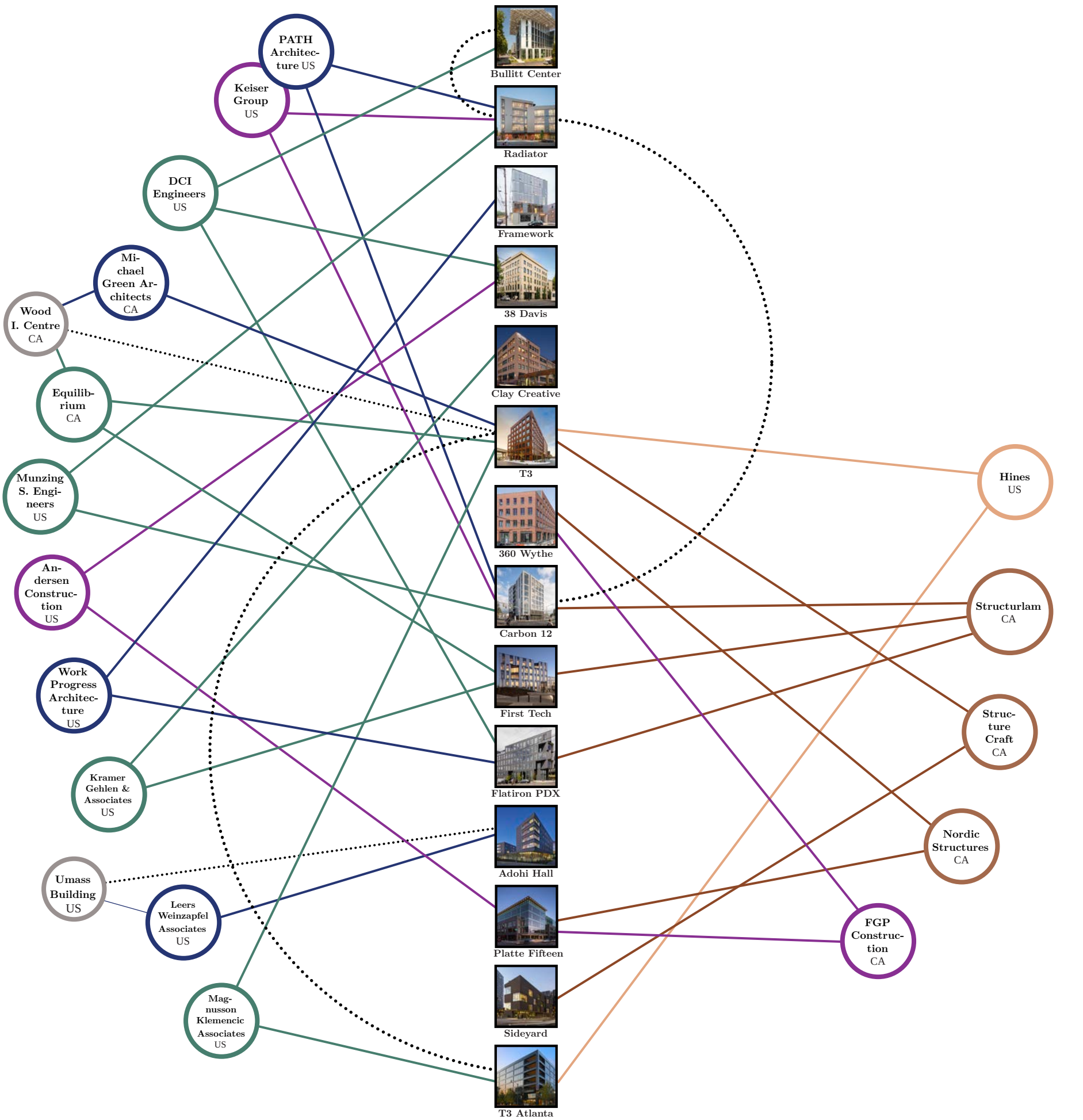

Figure 6.15: Relationships between American case-studies, policies and their stakeholders

Table 6.13: List of stakeholders involved in American case-studies

Project *(name)*	**Architect** *(name, country)*	**Engineer** *(name, country)*	**Timber Engineer** *(name, country)*	**General Contractor** *(name, country)*	**Timber Contractor** *(name, country)*	**Timber Supplier - Structural elements** *(name, country)*	**Timber Supplier - Floor slabs** *(name, country)*	**Client/Developer** *(name, country)*
Bullitt Center	The Miller Hull Partnership, US	DCI Engineers, US	DCI Engineers, US	Schuchart, US	Calvert Glulam, US	Calvert Glulam, US	Calvert Glulam, US	The Bullitt Company, US
Radiator	PATH Architecture, US	Munzing Structural Engineers, US	Munzing Structural Engineers, US	Kaiser Group, US	Timberland Framing, US	Rosboro, US	Rosboro, US	Kaiser Group, US
Framework	Work Progress Architecture, US	TM Rippey Engineers - Don Cushing Associates, US	Frank Lumber Company, US	Yorke and Curtis, US	Frank Lumber Company, US	Frank Lumber Company, US	Frank Lumber Company, US	Urban Development Partners, US
38 Davis	Ankrom Moisan Architects, US	Humber Design Group, US	DCI Engineers, US	Andersen Construction, US	n/a	Local	Local	Gerding Edlen, US
Clay Creative	Mackenzie Architects, US	Kramer Gehlen & Associates, US	Kramer Gehlen & Associates, US	Turner Construction Company, US	Turner Construction Company, US	n/a	n/a	Killan Pacific, US
T3	Michael Green Architects, CA - DLR Group, US	Magnusson Klemencic Associates, US	Structure Craft, CA	Kraus Anderson Construction, US	Structure Craft, CA	Hasslacher Norica Timber, AT	Structure Craft, CA	Hines, US
360 Wythe	Flank, US	Tharpe, US	Nordic Structures, CA	n/a	FGP Construction, CA	Nordic Structures, CA	Nordic Structures, CA	Flank, US
Carbon 12	PATH Architecture, US	Munzing Structural Engineers, US	Munzing Structural Engineers, US	Kaiser Group, US	Structurlam, CA	Structurlam, CA	Structurlam, CA	Kaiser Group, US
First Tech Federal Credit Union	Hacker, US	Kramer Gehlen & Associates, US - Equilibrium Consulting, CA	Kramer Gehlen & Associates, US - Equilibrium Consulting, CA	Swinerton Builders, US	Structurlam, CA	Structurlam, CA	Structurlam, CA	First Tech Federal Credit Union, US
Flatiron PDX	Work Progress Architecture, US	DCI Engineers, US	DCI Engineers, US	Abbott Construction, US	Structurlam, CA	Structurlam, CA	Structurlam, CA	n/a
Adohi Hall	Leers Weinzapfel Associates, US	Holzpak, US	Holzpak, US	Nabholz, US	Holzpak, US	Binderholz, AT	Binderholz, AT	University Arkansas, US
Platte Fifteen	OZ Architecture, US	KL&A, US	KL&A, US	Adolfson & Peterson Construction, US	FGP Construction, CA	Nordic Structures, CA	Nordic Structures, CA	Crescent Real Estate, US
Sideyard	Skylab Architecture, US	Harper Houf Peterson Righellis, US	catena engineers, US	Andersen Construction, US	DR Johnson, US	DR Johnson, US	DR Johnson, US	Key Development, US
T3 Atlanta	Hartshorne Plunkard Architects - DLR Group, US	Magnusson Klemencic Associates, US	Structure Craft, CA	New South Construction, US	Structure Craft, CA	Structure Craft, CA	Structure Craft, CA	Hines, US

6.3.14 Australia

see Appendix pages 506-514

The Australian case studies were strongly influenced by private developers and investors who built the case-studies under the collaboration or influence of some Australian cities. This is the case of Melbourne, which declared its intention to achieve complete climate neutrality by 2020. *Forté* was designed in this favourable city-environment. The international construction company Lendlease (which has its headquarter in Sydney) decided to invest in a pilot project to test new paths for sustainable construction promoted by the city, and completed the building in 2012. Until the realisation of *Forté*, the Building Code of Australia was not allowing timber structures above three-stories without specific fire engineered solutions for CLT. Because Lendlease committed to realise other buildings like *Forté*, the company financed the necessary fire testing. The fire restrictions obliged the designer to leave visible only few timber structural elements with a calculated char layer, and the rest of the structure had to be enveloped in gypsum boards (Lendlease, 2013). Partner in this project was the company KLH which delivered the CLT from Austria to Australia. KLH completed some years before *Stadthaus* in London, which shares with *Forté* many technical solutions. After *Forté*, Lendlease completed in the United Kingdom two other case-studies *Cobalt Place* and *Trafalgar Place* both completed in 2015. Lendlease was also involved in the project *Library at the Dock* completed in Melbourne in 2014. The building is a three-storey project delivered through a tri-partnership agreement between Places Victoria, the City of Melbourne and Lendlease, and was the first public building in Australia to be constructed using CLT technology (Hayball, 2014).

In 2016 the proposal was accepted to change the code from a Deemed-to-satisfy (DTS) provision to a Performance solution approach. The national building code was then officially changed in 2019, and since then timber buildings up to 25 meters (typically eight-storeys) are allowed with a DTS provision (FTMA News, n.d.). In light of these changes, many Australian projects were planned and completed in the years 2018-2019. The design of the timber structure of *Daramu House* was carried out in parallel with a concrete one in order to prove that the timber structure was cost-competitive. According to the architect, the timber structure was as expensive as the concrete one thanks to the quick erection time of timber (Evans, 2018). The city of Brisbane won several awards for its sustainability policies, programming and commercial incentives. Here, *25 King* was designed by Bates Smart with the goal of following these sustainability targets (Lake et al., 2017). The building is enveloped in a high performance facade which allowed timber to be left visible. The building is also located in an area with many historical wood pavilions. The architects used a timber structure to create a tie to the existing heritage. Furthermore, all the elements which compose the structure of *25 King* could no longer be modified at the building site, due to structural approvals. The fact that the elements arrived at the building site pre-prepared, along with their lightweight properties, allowed the structure to be erected quickly (Lake et al., 2017). With these buildings, *Forté*, and the two other *Kambri* projects, the developer Lendlease built five of the nine Australian case-studies, being a true driver of MTBs in Australia. Lendlease

also was involved in two case-studies in the UK, and favoured the timber structures in them too.

In other two case-studies the influence of the developer resulted in a determination to consider timber structures. *Aveo Norwest*, and *The Macarthur Gardens* were both built by the Australian general contractor Strongbuild, who established an exclusive partnership agreement with the Austrian manufacturer Binderholz for the usage of the necessary CLT (AdvantageAustria.org, 2017). Stronguild was not new to timber structures as its headquarter was built with visible glulam beams and columns. *Aveo Norwest* was realised in timber thanks to the strict time schedule that would have made other methods prohibitive (CTBUH, 2017). *The Macarthur Gardens* were built with timber because the same team proposed it to the client. In light of the know-how learned from *Aveo Norwest* and because *The Macarthur Gardens* had to be delivered following a strict time schedule, the team successfully convinced the client to consider the timber alternative (MakeitWood, 2020). Both Strongbuild and Lendlease do have manufacturing facilities that are used to create the prefabricated components once the timber hits Australian shores. Strongbuild's 8,000 m^2 facility is based in Sydney's Baulkham Hills while Lendlease's Designmake prefab building components manufacturing warehouse recently opened in Western Sydney (Timberbiz, 2016).

Gilles Hall like *Kambri* projects both had as client an Australian public University (Monash University and Australian National University). All the three buildings (*Kambri* is composed by two case-studies) were the result of an architectural competition process. The reasons behind the choice of timber in *Gilles Hall* was that the university has been working towards 2039 net zero targets. As such, they were interested in pursuing timber construction for its carbon benefits (Topliss, 2020). *Kambri* was built with timber because the winning team formed by the developer Lendlease and the architectural office BVN proposed timber in the competition, and they were considered credible by the jury, thanks to the previous experience of Lendlease in Australia (Titchkovsky, 2018). Xlam Dolomiti supplied *Gilles Hall*, and Stora Enso provided the EWPs for the *Kambri* projects.

Finally, the client of *55 Southbank Boulevard* wanted to add hotel rooms on the top of his existing building. A CLT-based structure resulted in a higher number of floors in comparison with a concrete alternative and therefore timber was chosen (Benbow, 2019). This was possible thanks to the properties of timber structures, which are light and easy to transport. *55 Southbank Boulevard* was designed by Bates Smart architects.

The analysis of the stakeholders evidenced strong relationships between the Australian projects. Two architectural offices (Bates Smart and BVN architects) built two case-studies each. Lendlease DesignMake (a company of the contractor Lendlease) is the most frequent engineering office, involved in five case-studies, followed by AECOM which was involved in three case-studies. Additionally, in most of the cases (except *Kambri*), the engineer of record is also the timber engineer of record. By the analysis of the timber manufacturer, all the EWPs used came from Europe (Austria the majority, and Germany and Italy one case each) (Li et al., 2018) (Angeli, 2019). The EWPs were delivered per ship by sea and arrived in the building site ready to be assembled. In the last years, CLT manufacturer emerged also in Australia and in the future they might be more

competitive with the European producers (Timberbiz, 2016).

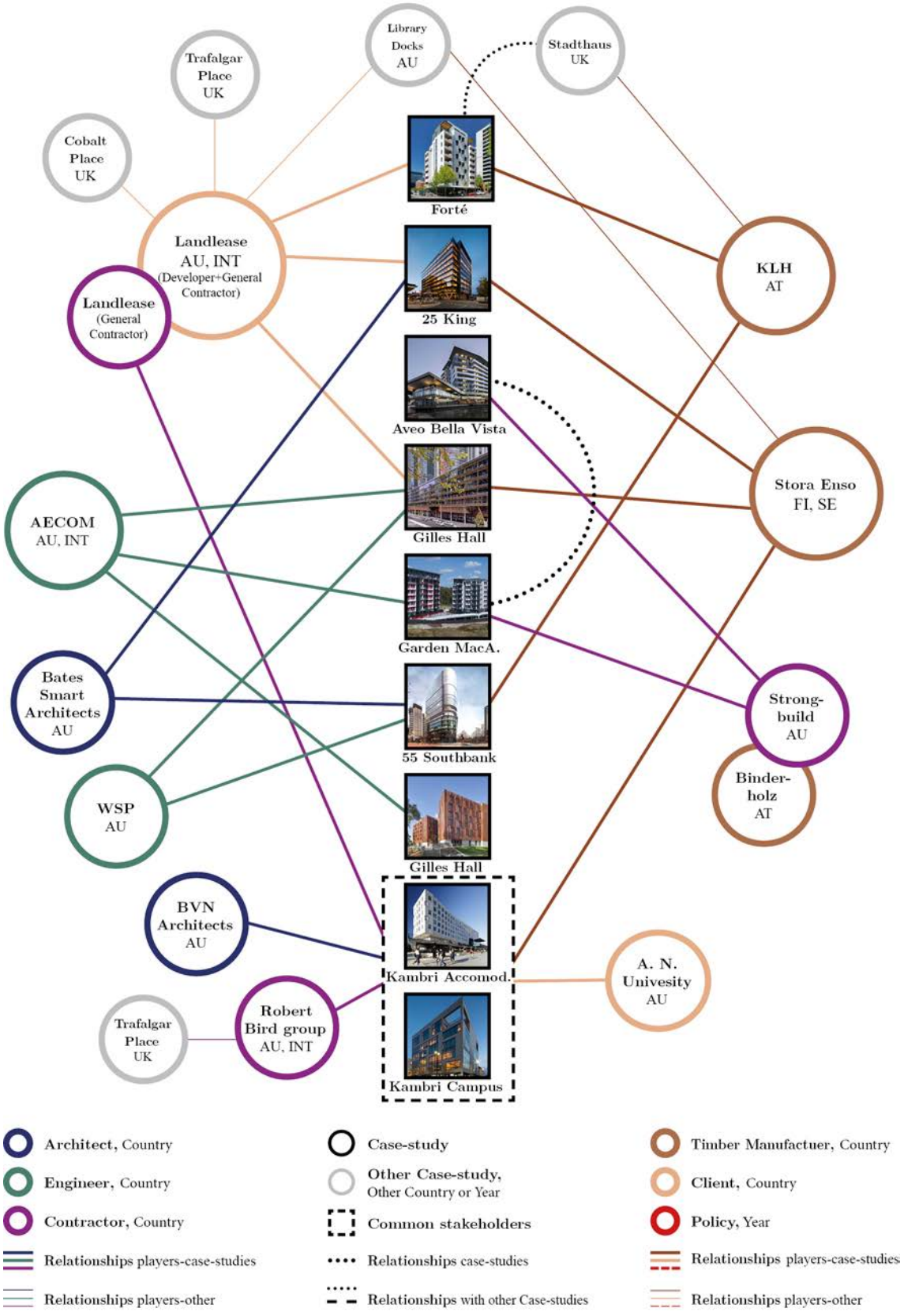

Figure 6.16: Relationships between Australian case-studies, policies and their stakeholders

Table 6.14: List of stakeholders involved in Australian case-studies

Project *(name)*	**Architect** *(name, country)*	**Engineer** *(name, country)*	**Timber Engineer** *(name, country)*	**General Contractor** *(name, country)*	**Timber Contractor** *(name, country)*	**Timber Supplier - Structural elements** *(name, country)*	**Timber Supplier - Floor slabs** *(name, country)*	**Client/Developer** *(name, country)*
Forté	Lendlease, INT	Lendlease - DesignMake, INT	KLH, AT	Lendlease, INT	KLH, AT	KLH, AT	KLH, AT	Lendlease, INT
25 King	Bates Smart Architects, AU	Lendlease - DesignMake, INT	Lendlease - DesignMake, INT	Lendlease, INT	Lendlease, INT	Wiehag, AT	Stora Enso, FI, SE	Lendlease, INT
Aveo Norwest	Jackson Teece, AU	Taylor Thomson Whitting, AU	Taylor Thomson Whitting, AU	Strongbuild, AU	Strongbuild, AU	Binderholz, AT	Binderholz, AT	AVEO, AU
Daramu House	Tzannes Architects, AU	Lendlease - DesignMake - Arcadis - WSP - AECOM, INT	Lendlease - DesignMake, INT	Lendlease, INT	Lendlease, INT	Hess Timber, DE	Stora Enso, FI, SE	Lendlease, INT
The Gardens Macarthur	n/a	AECOM, INT	AECOM, INT	Strongbuild, AU	Strongbuild, AU	Binderholz, AT	Binderholz, AT	BlueCHP, AU
55 Southbank Boulevard	Bates Smart Architects, AU	WSP, AU	Vistek, AU	Atelier Projects, AU	KLH, AT	KLH, AT	KLH, AT	Hume Property Group, AU
Gillies Hall	Jackson Clements Burrows Architects, AU	AECOM, INT	AECOM, INT	Multiplex, AU	Xlam Dolomti, IT	Xlam Dolomti, IT	Xlam Dolomti, IT	Monash University - MRS, AU
Kambri - Student housing	BVN Architects, AU	Robert Bird Group, AU	Lendlease - DesignMake, INT	Lendlease, INT	ABS, AU	Stora Enso, FI, SE	Stora Enso, FI, SE	The Australian National Univesity, AU
Kambri- Campus Building	BVN Architects, AU	Robert Bird Group, AU	Lendlease - DesignMake, INT	Lendlease, INT	ABS, AU	Stora Enso, FI, SE	Stora Enso, FI, SE	The Australian National Univesity, AU

6.3.15 Other Countries

see Appendix pages 516-518

As for the structural analysis, the influences in the case-study of this group were all different.

The main structural issue in the New Zealand buildings are earthquakes due to the high seismic zone of the country. Because LVL production in New Zealand is particularly developed, the research and develop was based on LVL solutions to improve the lateral resisting systems for earthquakes (Mayo, 2015). One of the leading figure in this process is the engineer and professor Andy Buchanan which developed post-tensioned rocking systems for timber structures (Buchanan et al., 2008). With these premises, the Massey University started in 2009 the process to realise a new educational building. An architectural competition was organised and was won by the team which designed *Te Ara Hihiko*. At the same time, the government set a policy to promote the use of timber in the region and build showcase examples (Mayo, 2015). In this positive context *Te Ara Hihiko* was designed and completed applying for the first time in the world a post-tensioned timber seismic frame, which *"flexes like a push-puppet toy during earthquakes"* (Mayo, 2015). The complex structural solutions utilized were so unique and had really few similar built projects, led the project to be constructed by Arrow International. Arrow International was familiar with the system because was involved in the *Nelson Marlborough Institute of Technology* project, a three-storey timber building based on a system similar to the one used in *Te Ara Hihiko*. The difference between previous built projects and *Te Ara Hihiko* is that for the first time a timber post-tensioned system was used in columns and beams rather the shear walls (Mayo, 2015).

The Taiwanese company Woodtek decided to build its headquarter *WoodTek HQ* which, according to the declaration of the company, had to symbolise the *"approach of Green Architecture development in Asia"* (ArchDaily, 2015). WoodTek is partner of KLH in Asia, and therefore the projects uses KLH CLT panels. The CLT panels lay on the top a concrete ground floor because of the possible termites attacks which are much higher in Taiwan compared with other countries (ArchDaily, 2015). The irregular volume of the building aimed to show the potentials of the CLT system (ArchDaily, 2015). Additionally, engineering was accomplished by the Canadian Equilibrium. Another Canadian company, Nicola Logworks, was also involved in the project.

Los Bronces is located near a mine in Chile. The private owner of the mine wanted fast erected buildings for the residence-hotel where the miners would be housed. For this reason, a joint research project was initiated in 2015 between a Chilean prefabrication company of modular wooden structures Tecnofast and the Pontificia Universidad Católica de Chile. The goal of the study was the technical feasibility of six-storey timber buildings made of modules to withstand the risk of earthquakes of the building site (Montaño et al., 2018).

The analysis of the context in these case-studies explained the reasons for the singular structure of *Te Ara Hihiko*, and showed once again how timber can be an international product, reaching different continents. Both *WoodTek HQ* (ArchDaily, 2015) and *Los Bronces* (in part) were supplied by an Austrian timber manufacturer (see Figure 6.17).

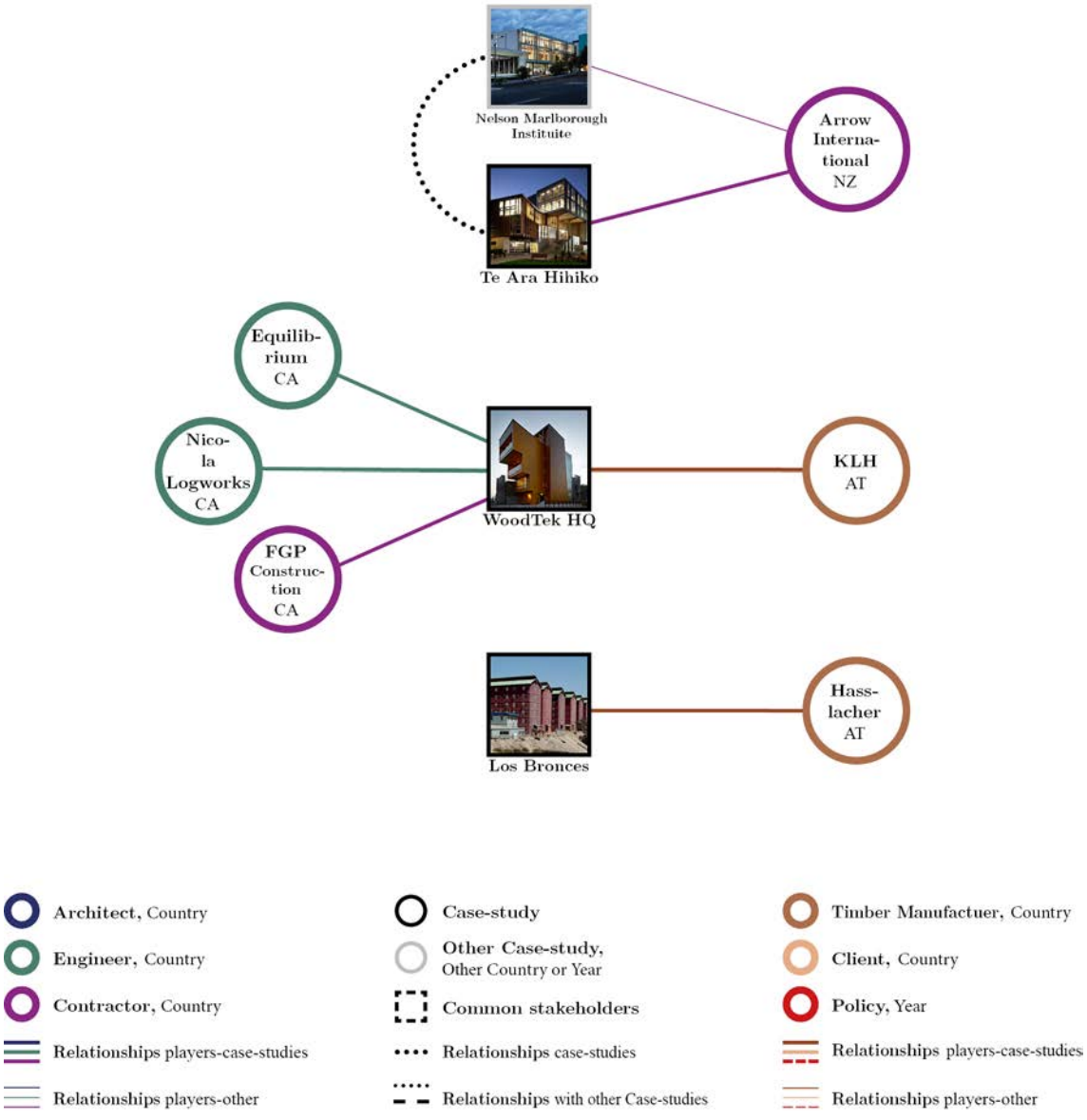

Figure 6.17: Relationships between case-studies, policies and their stakeholders in other countries

Table 6.15: List of stakeholders involved in the other case-studies

Project *(name)*	**Architect** *(name, country)*	**Engineer** *(name, country)*	**Timber Engineer** *(name, country)*	**General Contractor** *(name, country)*	**Timber Contractor** *(name, country)*	**Timber Supplier** **- Structural elements** *(name, country)*	**Timber Supplier** **- Floor slabs** *(name, country)*	**Client/Developer** *(name, country)*
Te Ara Hihiko	Athfield Architects, NZ	Dunning Thornton Consultants, NZ	Dunning Thornton Consultants, NZ	Arrow International, NZ	Nelson Pine Industries - Hunter Laminates, NZ	Nelson Pine Industries - Hunter Laminates, NZ	Nelson Pine Industries - Hunter Laminates, NZ	Massey University, NZ
WoodTek HQ	Origin, TW	n/a	Equilibrium - Nicola Logworks, CA	Shaing-Yang Construction, TW	KLH, AT	KLH, AT	KLH, AT	WoodTek, TW
Los Bronces	n/a	n/a	n/a	Tecno Fast, CL	Grupo ASAP, CL	Lamitec Chile - Voipir Chile, CL - Hasslacher Norica Timber, AT	UFP Camfor, US - CMPC Chile, CL	Anglo American, INT

6.4 Why MTBs Were Built and Who Built Them

The country context analysis provided several insights which have been collected and discussed in this section. Chapter 4 and especially Chapter 5 highlighted some trends and points of difference between the case-studies and the countries. This chapter adds another layer to the description and in some cases clarifies the reasons in which these buildings differ. The reason behind the similarities and differences, as shown in this chapter, often lies with the stakeholders involved. This section's intent is to recollect the main findings from the countries and compare them in order to add additional insights to the research.

6.4.1 Regulatory Framework and Policies

As the literature suggests, in the analysis of the drivers carried out previously, the building code limitations and its fire safety requirements affected the design of the case-studies, especially regarding the indoor timber exposure, the facade cladding, and the heights. The influence of these regulations are evident in most case-studies and countries analysed. This is particularly true for Central Europe, where the high amount of hybrid buildings was influenced by the fire regulations in many regions, such as Austria, Germany, and Switzerland. Similarly, in counties like the United Kingdom and Italy, the regulations allowed for fire escape routes and other structural elements to be built with timber, but then requested full encapsulation.

Although the regulations tended to influence the final design of the buildings, and in particular their height, this was not always the case. The analysis brought forth some relevant examples in which the design team or the clients successfully bent the existing limits and successfully completed buildings which were higher than the rules normally allowed. Examples of this were *Cenni di Cambiamento*, or *Carbon 12*. In the first project, the design team successfully lobbied for the modification of the Italian building code which was later approved by the Italian government (Mayo, 2015) (Fava, 2016). *Carbon 12* was financed by a private investor, and the city of Portland decided to allow the height of the building even if such height was not allowed at the time. *Wood Innovation Centre* had a similar history, but the team was able to use leverage based on the conditions written in the newly built act of British Columbia. *Wood Innovation Centre* then became a reference in this type of code.

A similar statement can be made in regard to the role that some policies played in the realisation and support of the early construction of MTBs. Very few early case-studies were built without any governmental (or related association) influence, even when the investor was private. The main tool in influencing the early realisation of MTBs were R&D joint projects between universities and industry, or professionals and governmental agencies acting as client or partial investors for the buildings. R&D projects involved mainly the public and private sphere in many case-studies. The application and the effects of this R&D was studied by Wiegand (2019) in some case-studies, and it will be left to be further researched in the future. What it is important to say here, is that the

transfer of knowledge of MTBs is as relevant as the regulation framework. Since the beginning, the structural and design challenges of MTBs have needed academic and professional research, which has only been made possible in later projects.

The analysis of the stakeholders made it possible to imagine the paths of the transfer of knowledge between the stakeholders involved. This relationship was highlighted when it became evident through the research. For example, the research program "Life Cycle One" led several players to consider technical solutions which were then applied both in *Life Cycle Tower* in Austria and *H7* in Germany, along with the composition of the core design-concept of the Austrian company CREE.

6.4.2 Main Influences and Motivations

After the analysis of the players involved and having understood the context by which each case study was influenced, it was possible to understand which drivers had the highest degree of influence. This section presents the case-studies divided by influence, and then by motivation. Figure 6.18 displays the trends on influences and motivations. With some exceptions, the majority of the case-studies are the result of private initiatives which were the major influence in 112 case-studies (56,9%). Public influence played a major role in 57 projects (28,9%), and public-private influenced 27 projects (13,7%). Only in one project was the influence (the public or private nature of the players) not clear. On a global perspective, sustainability was the main motivation for the investors for building an MTB. Secondly, technical aspects connected with building with timber were indicated by the stakeholders in a second numerous group of projects (24,5%). Both these tendencies were already addressed by (Gosselin et al., 2015) in a smaller sample of projects.

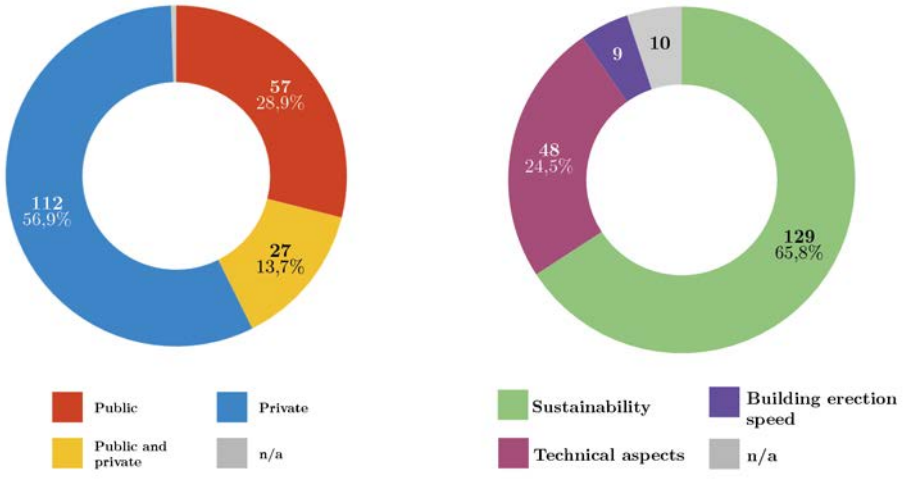

Figure 6.18: Overall trend regarding influences and motivations

These tendencies are not true in all the countries analysed. Figure 6.19 shows the ratio between private, public or cooperation between private and public influences in each country. The majority of case-studies in Scandinavian countries, along with Germany and Austria, have been more affected by public, or a combination of public and private influences. The city of Vienna and of Växjö were particularity active in the support of MTBs.

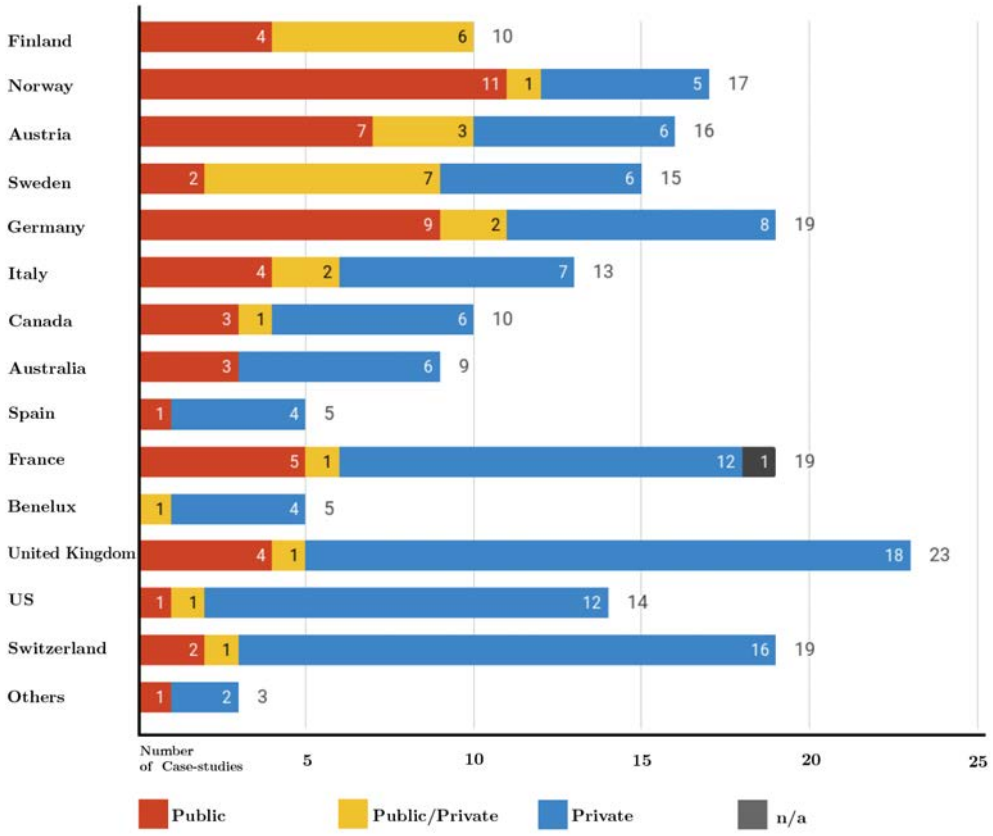

Figure 6.19: Public and private influence

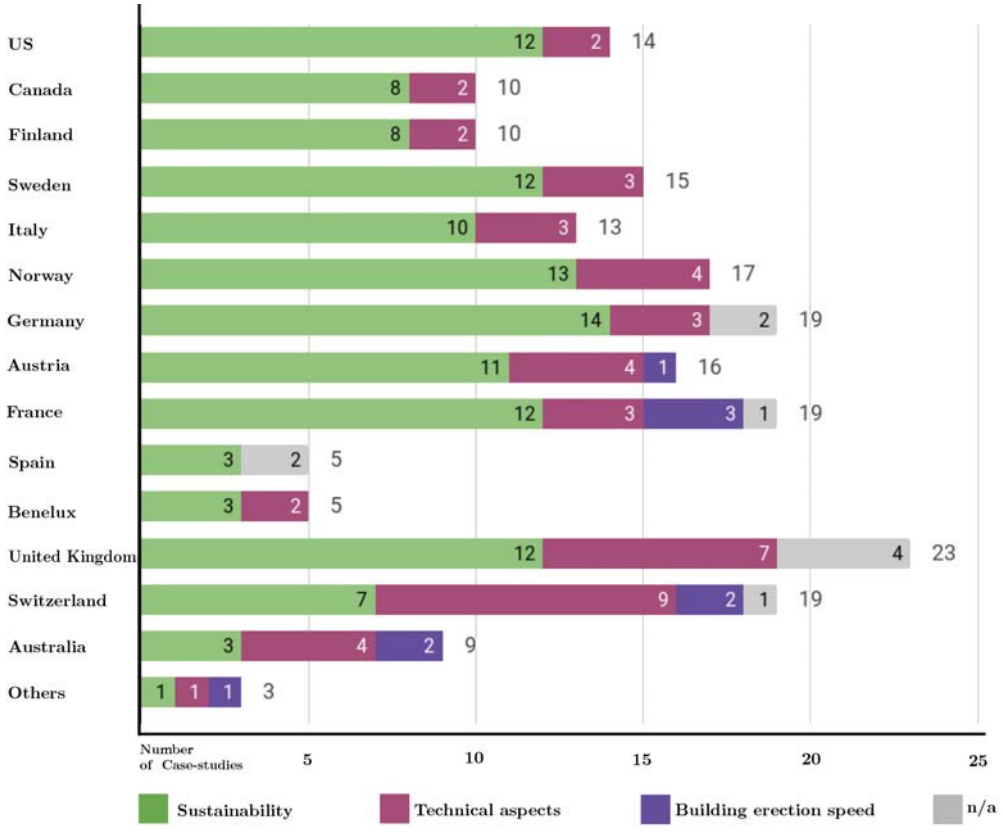

Figure 6.20: Motivations

Both the city influenced several projects with direct or indirect strategies like architectural competitions financed by the cities' public housing agency, or by dedicating specific areas of their territory to sustainable developments built and owner by private. Finland in particular, has a strong public influence on projects, thanks to many joint-ventures between the public and the private sector or the involvement of Finnish cities. Additionally, the public influence of the Province and the University of British Columbia was a major driver in the Canadian case studies in British Columbia. In all the other countries private investors were the major influence.

It is also worth mentioning that is some private case-studies, the country or the authorities were involved in part in the regulatory framework which then allowed the building to be built. As stated by Roos et al. (2010), authorities play a key role in the successful construction of MTBs. A perfect example of this is the positive influence the Hackney council had on its district (Fourthdoor, n.d.*c*).

While Figure 6.19 showed the overall main influences, Figure 6.20 displays the declared motivations which led to the realisation of each case-study. The desire to build a sustainable building was the main motivation of the public or private investors in the majority of the countries analysed. Only in Switzerland and Australia, other reasons were more frequent, in particular technical aspects related to timber structures. Several case-studies in each country were built due to timber's properties. Because timber is so lightweight, a timber structure was considered the only option for several projects like *Origine Condos* or *District 03* in Canada. Other times the same lightweight properties were favourable from an economical point of view, like in the case of *55 Southbank Boulevard*: thanks to timber, the hotel could have more bedrooms. Noise reduction issues, along with the ease of transportation were two particular reasons in campus or university projects. Ease of transport and the ability to erect the structure quickly were the major reasons for choosing timber, when the project needed to be completed quickly. Timber and BIM played a particularly coordinated role in many case-studies, with the latter being a system that coordinates and manages the time schedule. All these aspects are not secondary. The marketability of timber also passes the test with successful examples of built case-studies, in which the difficulties of the building site were solved by the qualities of timber construction.

The analysis of the influences and motivations laid out the role played by public and private investors in the realisation of MTBs. The global trend is leaning towards private initiatives, however there are several countries in which public influence played a more relevant or influential role. The analysis of the motivations showed that 66% of the projects build because of sustainable reasons. In many cases, the private desire of building a sustainable building, led to the realisation of the tallest examples like *HoHo Wien* and *Mjøstårnet*. Alternatively, many case-studies were completed thanks to the sustainable goals set by public players or cities. The latter are well represented by cities like Vienna, Växjö, Hackney in London. The high number of projects built due to timber's properties proves that timber is a versatile and adequate construction material also for complicated building sites and contexts.

6.4.3 Architects, Engineers and Contractors

The analysis of the stakeholders in each country discussed observations on the role of the design influences and the amount of projects in which they were involved. Many countries like the United Kingdom, Austria, and Norway have highly interconnected relationship networks between case-studies and stakeholders. From this it was clear that while the regulatory framework played a considerable role, in some countries only a few players design, calculate, build or commission the MTBs in their nation. The analysis of the context also identifies some key-players (designers, engineers, contractors, and developers) which strongly influenced the realisation, the R&D and the design properties of some case-studies. In this section the role of the architects, engineers and general contractors is further discussed. The following section will be dedicated to the timber contractors and manufacturers.

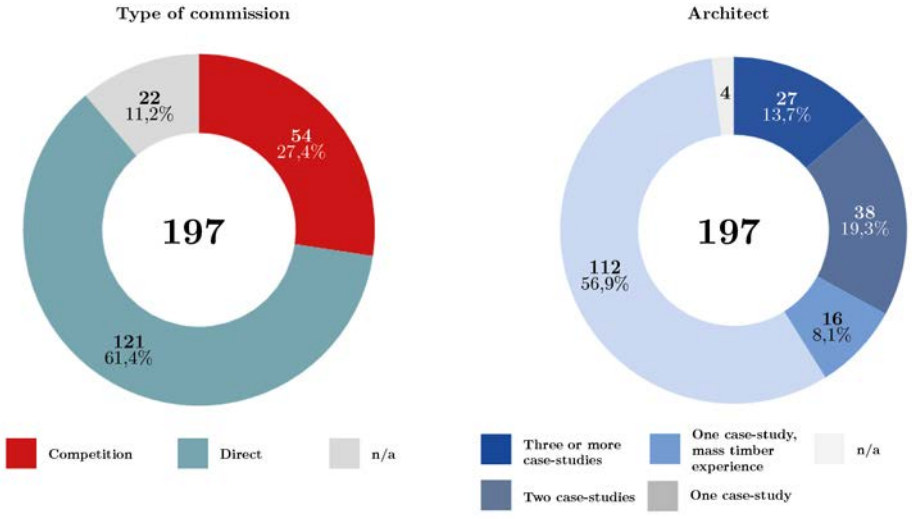

Figure 6.21: Overall trends regarding type of commission and recurrent architects

Architects of MTBs tend to design in their own country. Very few case-studies were designed by foreign architects, and even architectural competitions tended to have local architectural offices. In Switzerland, the Japanese architect Shigeru Ban designed two case-studies. Some case-studies were found to be a collaborative work between a local architectural office and a foreigner office. This is the case for the teams of *Egnes Park* (Norwegian-Dutch architects), *Sørhauggate* (Norwegian-Austrian architects), and *UBC Brock Commons* (Canadian-Austrian architects). The majority of the case-studies were commissioned directly (see Figure 6.21). Even if in countries like Austria and Switzerland, the majority of the case-studies were the result of an architectural competition, all the winning teams were local architects, except for the *Omega Headquarters*, won by the Japanese Architect, Shigeru Ban. In Austria in particular, the high number of competitions is connected to the city of Vienna, which organised them. The practice of architectural competitions is also common in Switzerland, where many privately founded projects were financed after winning the proposal. Only in the United Kingdom and Norway are the majority of the projects designed by

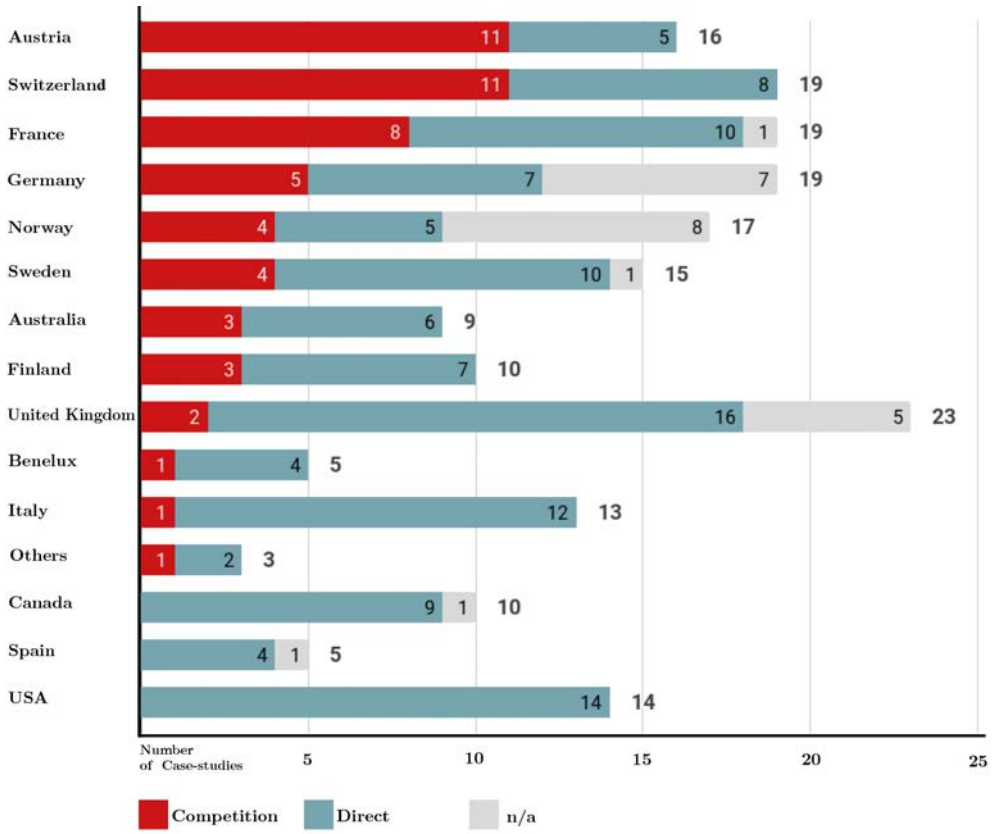

Figure 6.22: Type of commission per country

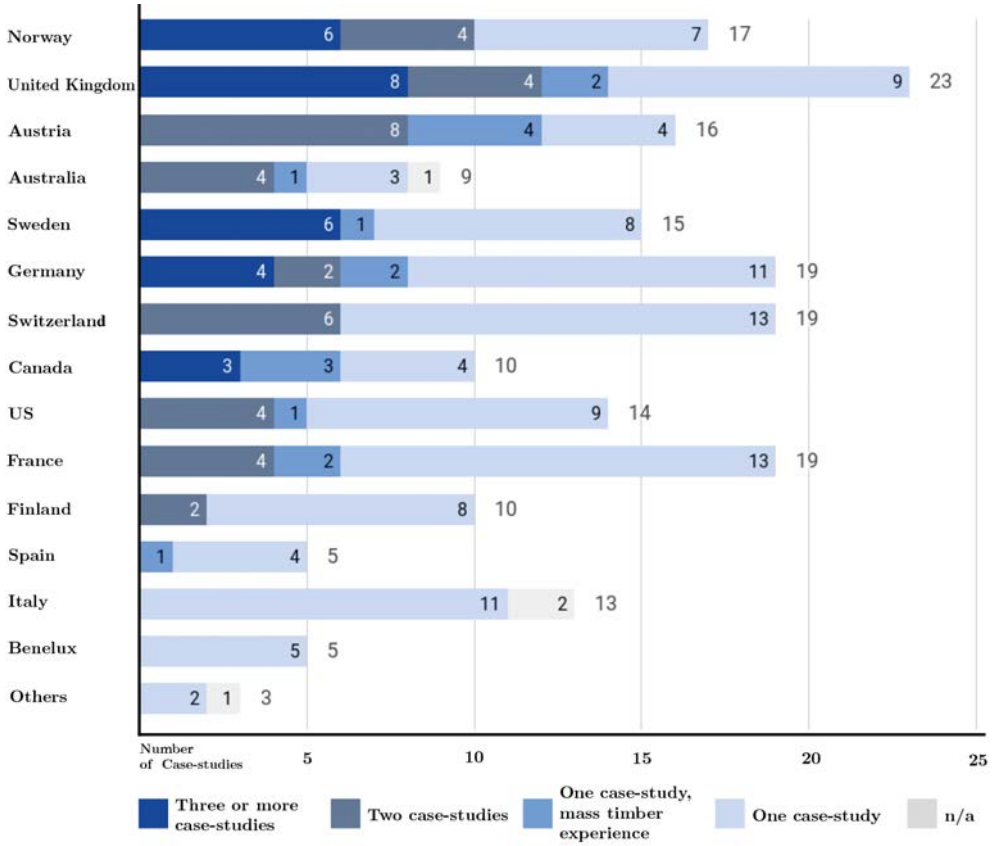

Figure 6.23: Recurrent architects per country

offices which had already designed more than one timber case studies. Half of Austria's cases are made up of offices which designed two or more timber case studies, with several offices having built one case-study in the survey, but had designed several relevant mass timber projects, like Hubert Riess and Dietrich Untertrifaller Architects. On the other hand, Italy, Spain, and Benelux all have different architectural offices which designed their case-studies. All in all, architectural offices are not highly repetitive in the design of MTBs, and only a few offices have built up a considerable amount of experience in this field. This is the case for offices like Hermann Kaufmann, Waugh Thistleton Architects or Kaden-Lager Architekten, which designed all their case-studies with similar technical solutions.

Timber engineers appear to be more repetitive than engineering offices and architects. Figure 6.24 shows that overall, 65% of the case-studies were designed by timber engineers who took part in more than one timber project. This percentage also consider that the timber structure of many projects were calculated directly by a timber supplier. From a global perspective, recurrent engineering offices are as frequent as architects.

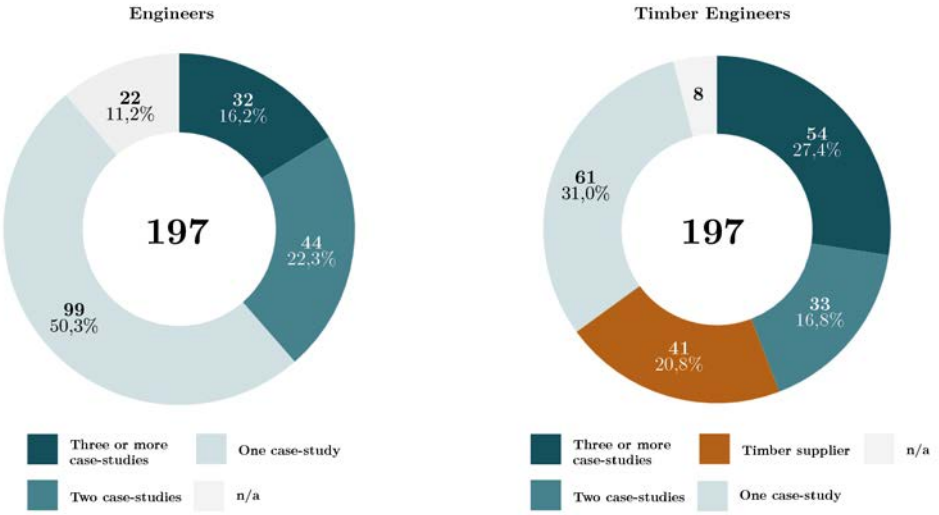

Figure 6.24: Overall trends regarding recurrent engineers and timber engineers

As previously stated, the engineer and timber engineer are not always coming from the same office. In the analysis of the countries, it appears that engineering offices occasionally sub-contract the calculation of the timber structure to other specialised offices. Other times, like the case of Woschitz Group in Austria, the offices are specialised in a wide range of structures, and they also calculate timber structures. These differences are evident in 6.25, when compared with Figure 6.26. Figure 6.26 shows how many case-studies are designed in each country by several degrees of repetition of timber engineering offices or timber suppliers (which provided timber engineering). Figure 6.26 shows a considerable amount of timber engineering offices were a part of more than one case-study. The United Kingdom, Australia, Norway, and Austria have the majority of their case-studies designed by more recurring timber engineers.

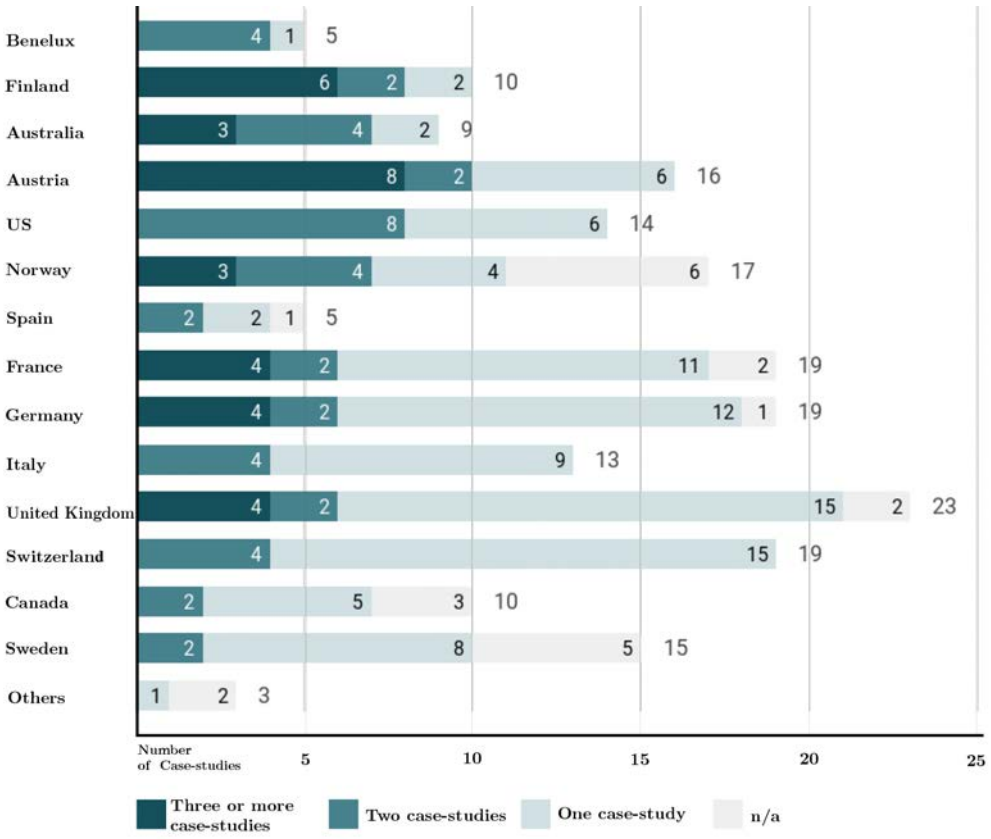

Figure 6.25: Recurrent engineers per country

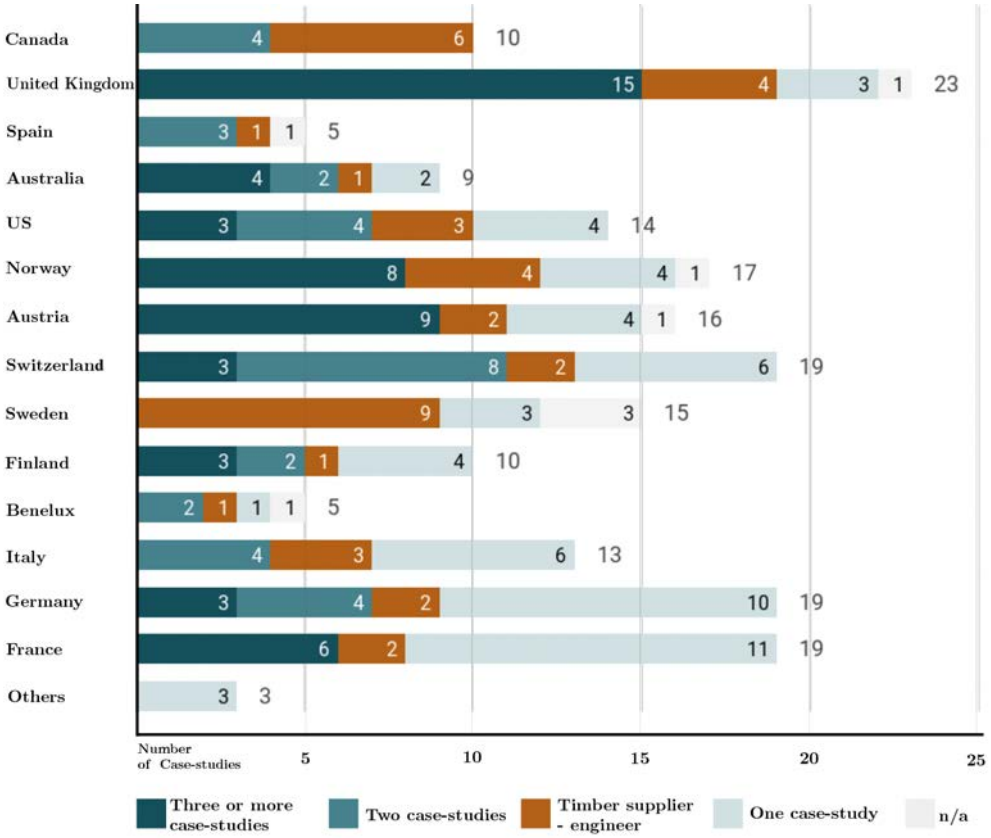

Figure 6.26: Recurrent timber engineers per country

Eurban, iTRE, Woschitz Group, Merz Klay are some of the offices with the highest number of case-studies built. Repetitive timber engineers are also found in countries with fewer case studies like Benelux or Spain. Only in Germany and France (besides the group formed by single countries "Other") the case-studies with a single office involved are more frequent than the case-studies designed by recurring offices. The calculation of the timber structural parts is a service which is offered also by some timber manufacturers. If we also include these types of additional professionals, we can see that in some countries, the number of recurrent figures involved grows. This is true for Canada, where all the case studies are designed by recurring timber professionals. In this regard, the company Martinsons can be considered a true key-player in Sweden, with the majority of the case-studies engineered by the Swedish timber manufacturer. The analysis carried out in Figure 6.26 therefore shows that the majority of the built case-studies is calculated by highly recurring and few timber offices or timber engineers of the timber manufacturer. While many timber engineers were involved in several case-studies, several of them were also involved in different projects in other countries. This is particularly evident in Europe through the exchange between Austria-Switzerland and Germany, with similar situations in Scandinavia and North America. Merz Klay (Austria), Pirmin Jung Ingenieure (Switzerland), Borlini&Zanini (Switzerland), Equilibrium (Canada) are some of the offices which designed at least one case-study in another country.

This analysis of the stakeholders concludes with the description of the contractors involved in the selected case-studies. The analysis carried out before, showed some key-players in the realisation of these projects. Companies like Eurban in the United Kingdom, Martinsons in Sweden, or Veidekke and Woodcon in Norway, all have a considerable amount of built projects, with all these companies having constructed the majority of the case-studies in their country. Figure 6.27 shows the percentage of case-studies built with repetitive contractors. While the number of general contractors is in line with the other professionals, in the case of timber contractors, the majority of the case-studies have been built by a company which was involved in at least one of the selected case-studies (66%).

Figure 6.27: Overall trends regarding recurrent general contractors and timber contractors

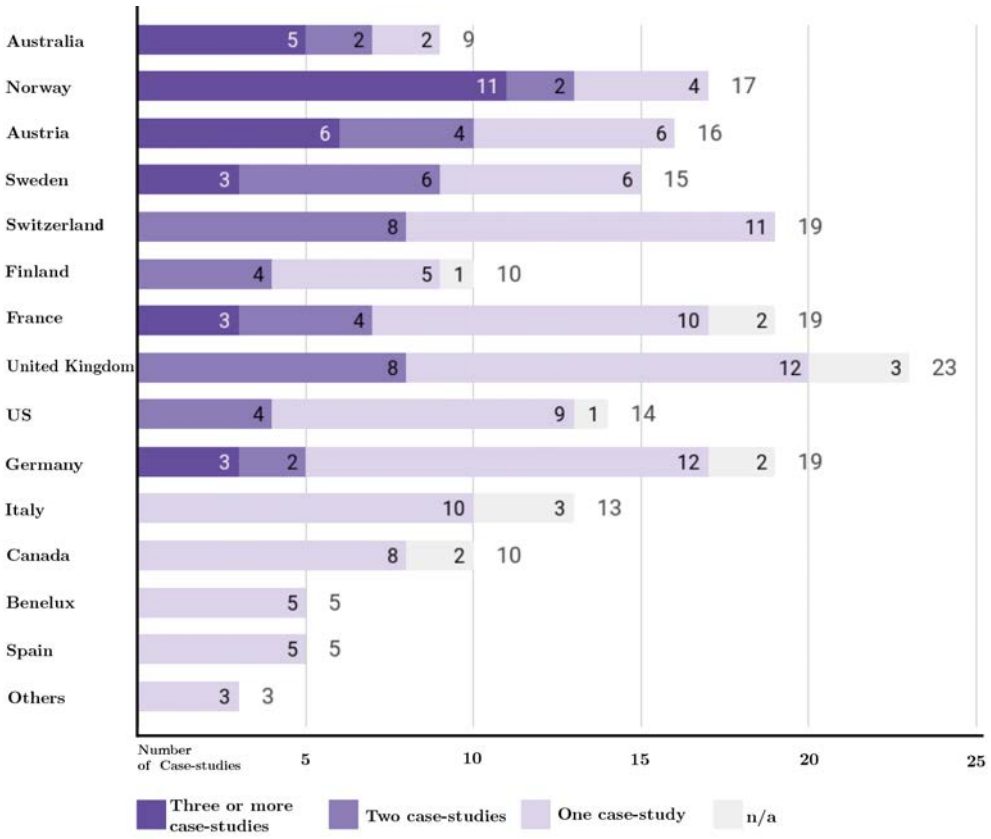

Figure 6.28: Recurrent general contractor per country

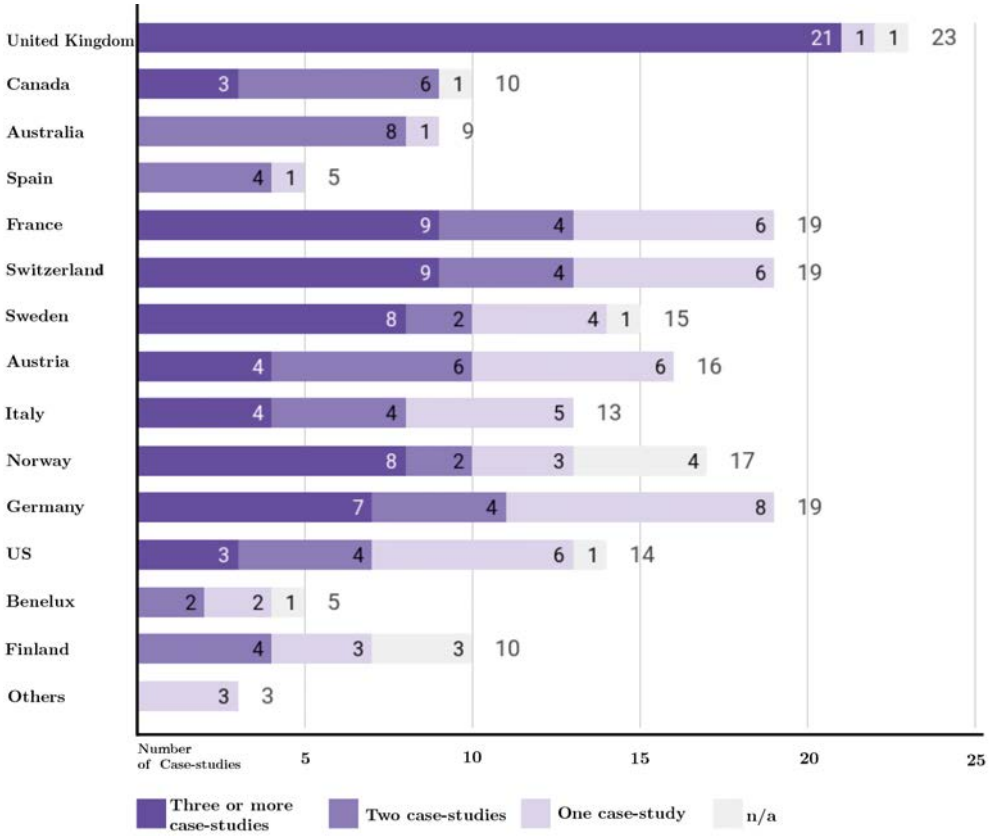

Figure 6.29: Recurrent timber contractor per country

The countries with the highest number of case-studies built by common general contractors are Australia, Norway and Austria. Lendlease in Australia, Veidekke in Norway and both Kaufmann Bausysteme and Kulmer Holzleimbau in Austria were previously identified in each country analysis as considerable drivers in the construction and realisation of the MTBs in their country. Meanwhile, Spain, Italy, Canada and Benelux all have different general contractors. Figure 6.29 shows instead that the timber contractors are much more repetitive. In the majority of the countries, the timber contractors are much more common professionals in the realisation of MTBs, and in some countries, like in the United Kingdom, 21 of the 23 case-studies were built by only three companies. Through these observations, it seems that timber contractors, together with timber engineers are the stakeholders with the necessary experience, however more research would be necessary to investigate the reasons behind this occurrence. In the *Kambri* projects in Australia, Lendlease was chosen because it was considered a competent company in light of the previous experiences gathered. This might be an example of why these few selected companies built the majority of the MTBs selected.

The analysis of the stakeholders involved in the design and construction of the selected MTBs confirmed in part some observations made by existing literature. In several countries there are a few designers or builders (or both) which designed the majority of the case-studies. The number of repetitive professionals is not the majority in the analysis of the architects, the engineers, and the general contractors, but is the majority of the case-studies built by timber contractors which were involved in at least one other case-study. As Ruuska and Häkkinen (2016) noted, *"there are only a limited number of designers experienced on timber construction"*. If in some countries it seems that the professionals are much more heterogeneous, it could be because there are more experienced players in the realisation of these buildings. What appears clear from this analysis, is that there is a need to learn from timber and there are very few professionals which have the necessary know-how.

6.4.4 Timber Suppliers

Through the analysis of the context for each country, the influence to the design that the timber suppliers sometimes have on the MTBs became very evident. Some companies, like KLH, supply mainly CLT, whereas other companies like Stora Enso or Martinsons, can supply a wider range of products. In the analysis made in this chapter, the timber suppliers were divided by the company which supplied the structural floors, and the companies which supplied all the other structural elements like columns, beams, shear walls, and core walls. In some cases, the companies were the same for the selected project, and in others they differed.

Figure 6.30 shows on the left the average[13] of how many case-studies relied on national timber manufacturers, and how many utilized EWPs provided by companies from another country instead.

[13]The average was made between the number of case-studies supplied by floor and strucutral elements, as later shown in Figure 6.31.

Slightly more than half of the case-studies used foreign EWPs for their structures, whereas 95 of them were supplied nationally. Because Austria has many CLT suppliers, this resulted in many case-studies supplied by Austrian timber manufacturers. Examples of projects where this was the case, even when the countries were not in close proximity to one another are, Australia, Taiwan and Chile. The other high percentage of projects is represented by the case-studies supplied by Stora Enso. Having Finnish and Swedish roots, it was considered separately. Figure 6.30 shows that 20,8% of the total projects were supplied only by Stora Enso. On the right, Figure 6.30 shows the actual percentage of the countries (or world macro-region) in which were located the actual sawmills which assembled the EWPs of the 197 selected case-studies. As it turns out, Austrian sawmills (owned by nationally or by foreign companies[14]) supplied slightly more than half of the total case-studies.

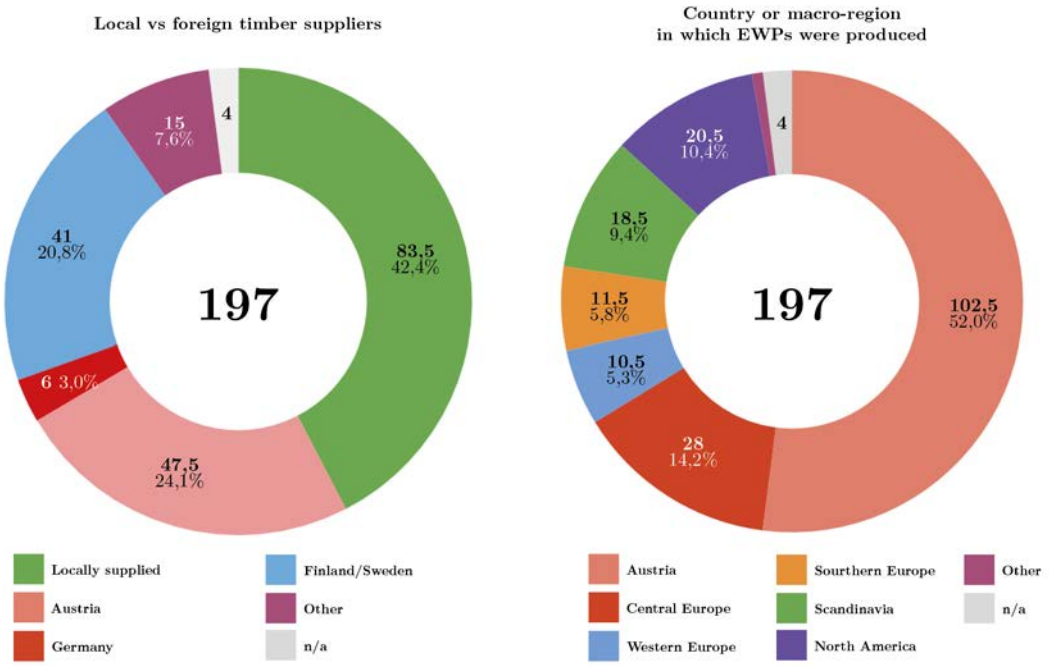

Figure 6.30: Overall trends between local and foreign timber suppliers

Figure 6.31 shows how many case-studies per country relied on national timber manufacturers, and how many utilized EWPs provided by companies from another country instead. The countries which relied mainly on national timber producers are Austria, Switzerland, Finland and Canada. All of these countries are famous for their timber products. The difference lies in the fact that Austria, Canada, and Finland also export their products, meanwhile Switzerland does not. The fact that Switzerland has mainly post-and-beams structures, is also connected to the fact that its CLT production is not as strong as in Austria, and the developers both for market reasons and for prices, prefer to use local EWPs products (mainly glulam based). Meanwhile, the United Kingdom and Australia imported all EWPs from European producers. Austrian companies along with Stora Enso (which is the only Finnish Swedish company considered) provided globally the highest amount of EWPs to other countries, except for the United States, which were mainly

[14] As noted previously, by the end of 2019 all of Stora Enso's CLT was actually produced in Austria (Jauk, 2017).

supplied by a Canadian timber manufacturer. Finland, Germany, Italy and Spain supplied some international case-studies as well. All in all, Figure 6.31 shows that timber can be both a local and international product. EWPs can reach different continents and be CNC tailored for a quick erection as shown in the Australian case-studies.

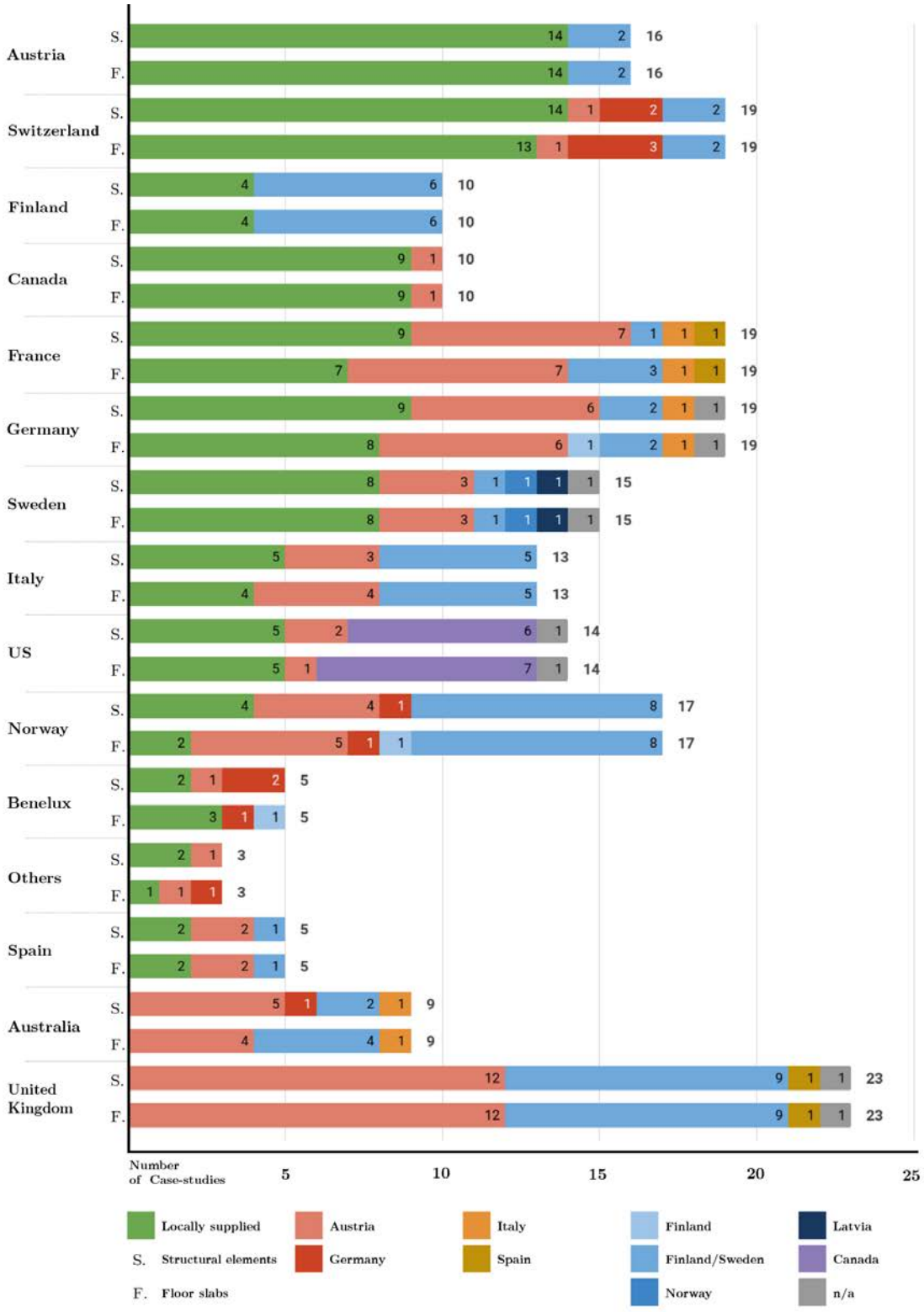

Figure 6.31: Local vs. foreign timber suppliers per country

6.4.5 Main Players in the Global Scenario

Through the analysis of the context in each country, and the comparison of them, it was possible to identify some main world drivers which not only contributed significantly to the design of MTBs in their country, but often were involved in the know-how transfer in other countries as well. These actors can be cities, professionals, or timber suppliers.

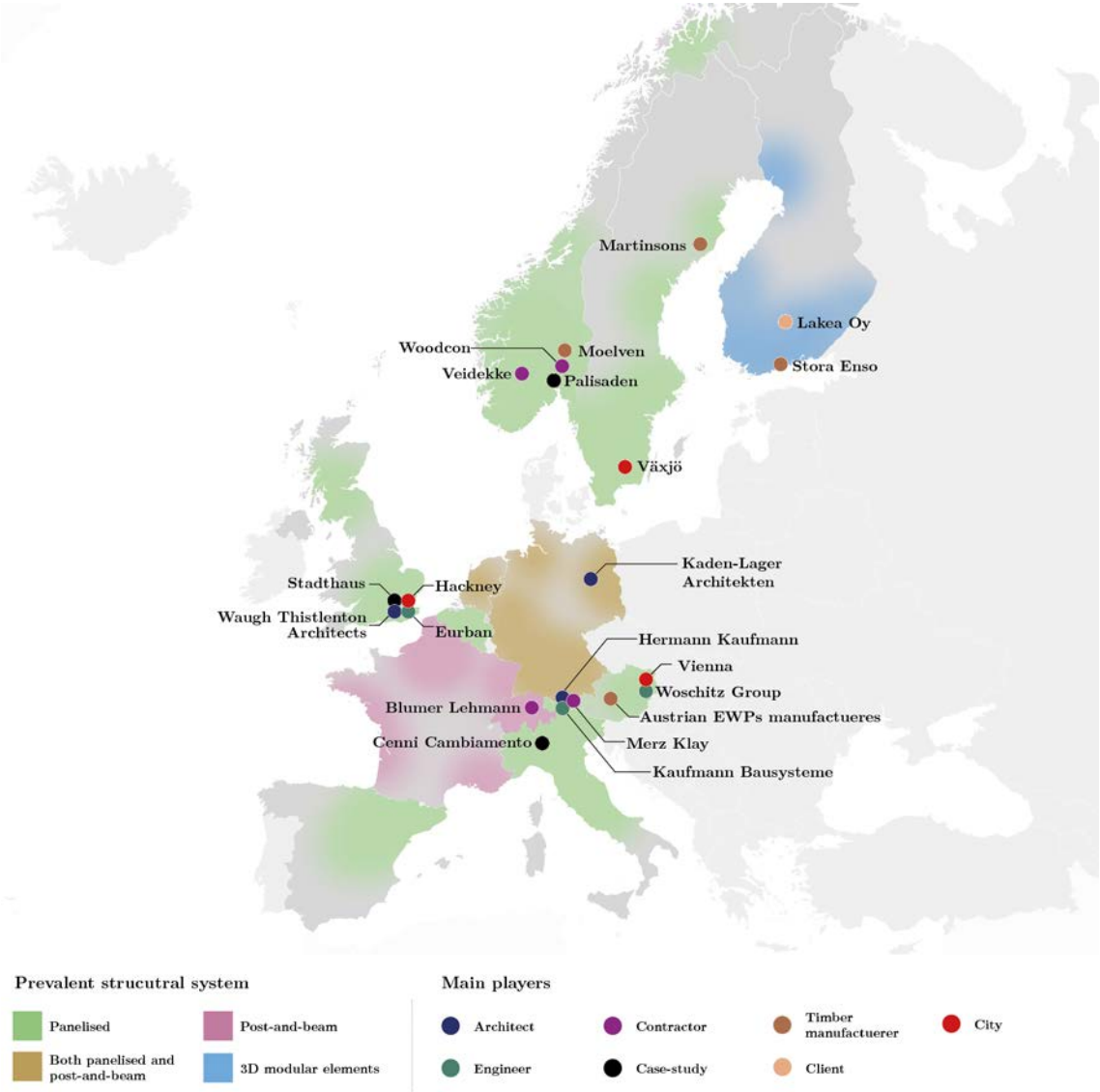

Figure 6.32: Prevalent structural systems and main players in Europe

In Europe, the structural system adopted by each country varies considerably. The difference lies especially within the regions which are generally considered homogeneous like Central Europe or Scandinavia (see Figure 6.32). In Central Europe, many professionals emerged as drivers of design and influence. In Austria, the city of Vienna proved to be a player in the early adoption of MTBs. Together with the agency ProHolz, the city-housing companies favoured the realisation of several case studies. Involved in the majority of the Viennese case-studies was the office Woschitz Group. With the engineering of the first Austrian MTBs, along with working on the two *HoHo* projects, Woschitz Group represents an engineering practice which combined timber and concrete.

Located in the west Voralberg region of Austria, Merz Klay, Hermann Kaufmann, and Kaufmann Bausysteme represent a different approach for the design of MTBs. The first two are established professional offices, with heterogeneous approaches, Kaufmann Bausysteme represents an example of an off-site 3D assembly contractor. The fact that the company was able to provide the 3D modules for the project *Woodie* in Hamburg (830 Km far from the assembly line) gives credence to the idea that this system is competitive for future projects, and is not locally constricted. Switzerland offered particularly relevant case-studies influenced by the company Blumer Lehmann's know-how. The company is well known for CNC and cutting edge timber structures. The case-studies where the company was involved (*Tamedia Office*, *Omega Headquarters*, and *Bjergsted Financial Park*) are examples of timber tailored elements, and of hybridisation not only between timber and concrete, but also between different EWPs. In Germany, the architectural office Kaden-Lager was behind some of the most representative projects in the country such as *E3* and *Skaio*, all having similar structural systems.

In Western Europe, the case-studies are numerous and heterogeneous. In Benelux, the case-studies were too few to observe a particular driver outside private initiatives. In France, the stakeholders were very different, with a few architects and engineering offices being involved in multiple case-studies. The high number of projects built in France, especially in the very last years of the survey, make the country a potential favourable ground for the research and realisation of MTBs in the future. In the United Kingdom two professionals emerged as major designers of the case-studies of that country: Waugh Thistleton Architects and Eurban. Both were involved in many case-studies and gained experience with panelised systems in particular. In addition to these two professionals, the council of Hackney played a consistently influential role. Thanks to the council, many projects were realised in the district of London, making it one of the most dense areas with MTBs in just 15 years. As seen in the context analysis, the project *Stadthaus* represented a considerable breakthrough in London and was a substantial achievement globally. The interest and media coverage of the project definitely influenced other British and world players in the industry.

A smaller amount of case-studies were realised in South Europe. Both Italy and Spain imported EWPs from other countries, and have mainly panelised concept case-studies. Both the countries have local EWP producers with companies such as Egoin, Rubner, and Xlam Dolomiti involved in national and foreign case-studies. *Cenni di Cambiamento* positively influenced the building code in Italy, and had an impact on many other projects. As with *Stadthaus*, *Cenni di Cambiamento* showed that building large scale timber projects was possible, especially with an all-timber structure.

Many drivers were observed in Scandinavia. As previously stated, the region has different MTBs practices, with Finland making major developments with 3D modular structures. This was observed due to the influence of Lake Oy, the major housing developer in Finland. Stora Enso was involved throughout its R&D "Urban Wood" 3D modular concept in the realisation of the majority of the Finnish case-studies, representing an example of a company that can influence the MTBs in its nation. In Sweden, the city of Växjö represented a major driver in the influence of the

MTBs, with successful programs and policies. Additionally, the timber manufacturer Martinsons was involved in the majority of the Swedish case-studies, thus becoming a reference point for many designers, especially for panelised systems. The Swedish company provided the majority of the projects' timber engineering services, making the practice of timber engineering in Sweden a niche topic for these structures.

In Norway, the student housing project *Palisaden* represented a breakthrough moment in the construction of MTBs in the country. Its successful completion initiated a series of similar student housing projects which were primarily built by two contractors, Veidekke and Woodcon. The "Trä8" structural concept developed by Moelven allowed the company to reach considerable heights with all-timber structures. The path initiated by Moelven with this R&D program allowed the company to differentiate its know-how in the development of all-timber structures for tall buildings. This was a considerable achievement for a highly hybrid global practice.

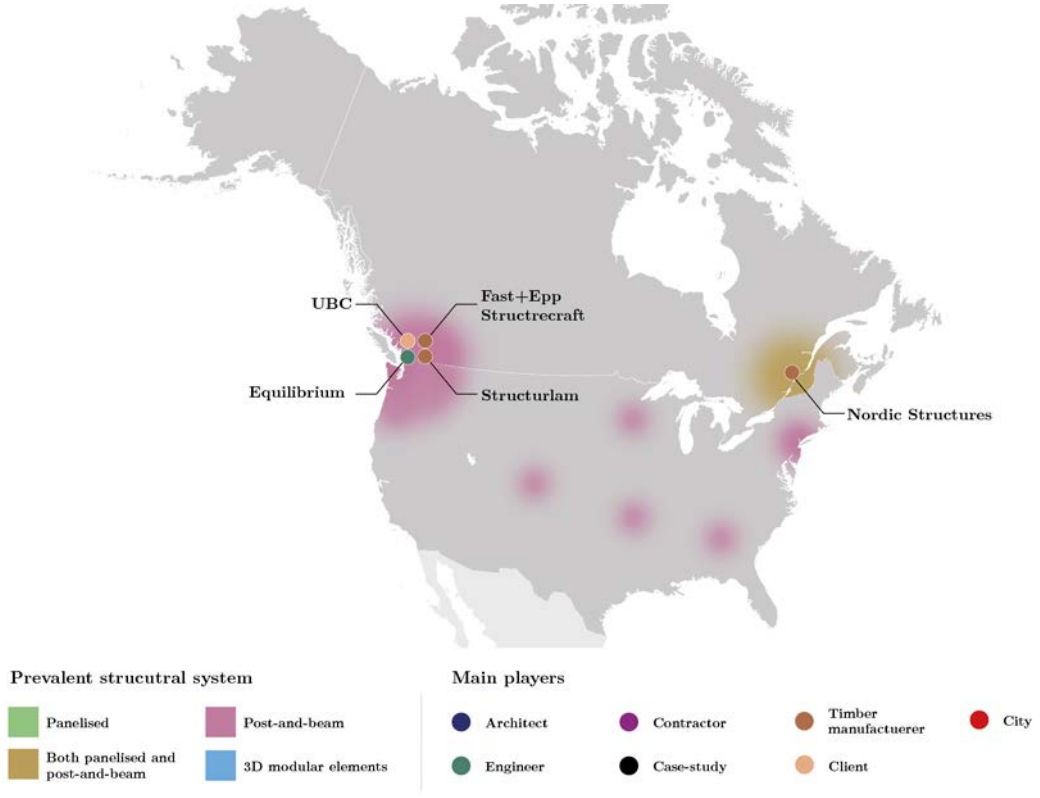

Figure 6.33: Prevalent structural systems and main players in North America

In North America, considerable predominance of post-and-beam structures was observed in Chapter 5. Additionally, Canada was divided in two "areas of influence". The first was British Columbia, where the public influence was higher, and where major drivers like the UBC commissioned the majority of projects. The British Columbia case-studies were also primarily designed by two engineering offices, Equilibrium and Fast+Epp, and supplied by Structurlam. The company StructureCraft was only involved in American case-studies, and represents an example of the supply-connection between this Canadian state and the Pacific North West Region of the US. The second area of influence took us to the East Coast, where the company Nordic Structures supplied the totality of the case-studies in Quebec. As Martinsons in Sweden, Nordic Structures provided timber en-

gineering services for the majority of its case-studies. The company also supplied other American case-studies. In the United States of America, the vast majority of the projects were office buildings, financed by private investors with sustainable goals. The country has the highest amount of projects that use NLT floors, with CLT only being widely used in the later years of this survey. The analysis of the context sometimes demonstrated that the choice of NLT was also due to historical reasons. Similar to France, the United States also has a considerable number of case-studies built in the last year of the survey, and the country seems to be a favourable ground for MTBs. Additionally, the code regulations in the US were recently modified, allowing MTBs up to twelve storeys tall.

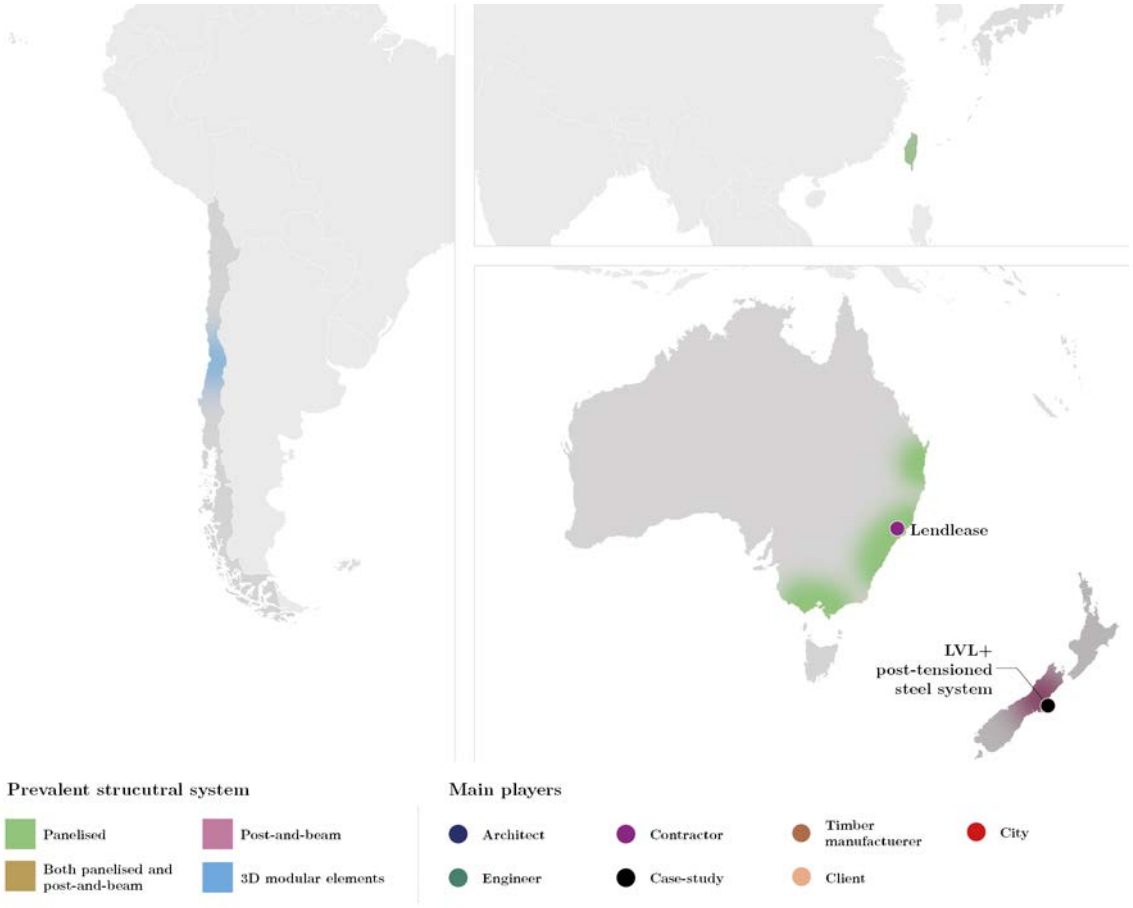

Figure 6.34: Prevalent structural systems and main players the other countries

Heterogeneous drivers were behind the other countries' case-studies. In Australia, the developer Lendlease was the major driver behind the realisation of many case-studies. After having financed the first Australian case-study *Forté*, the company successfully improved its expertise in MTBs in Australia with several other projects. In Taiwan a private initiative made the realisation of *WoodTek HQ* possible, which involved both Canadian and Austrian know-how. Also, the case-study in Chile featured EWPs from Austria, and demonstrated a positive relationship between a public university and private joint research. In New Zealand, the case-study *Te Ara Hihiko* represents an example of the specific R&D carried out in the country. The seismic requirements, together with the high production of LVL in the country, made it necessary to consider alternative systems which resulted in the final structure of *Te Ara Hihiko*.

6.5 Conclusions

In this chapter the stakeholders and influencers were identified and related to the findings of Chapter 5. The contextual analysis was carried out by subdividing the categories of analysis into several groups. The origin of the commission and its nature, the public or private influence, together with the identification of the main professionals involved, were all researched and compared.

Many findings emerged from this chapter. The description of the context of the country, provided the narrative regarding the evolution of the practice of MTBs in each country. The analysis showed that there is heterogeneity in the influences affecting the selected MTBs. Some countries have highly intertwined relationships with the building code, the professionals, the R&D programs, or all of these combined. Some case-studies also show that the building code can be lobbied and modified in order to allow the realisation of a building project. What emerges from the analysis is that MTBs are the result of previous research studies, were affected by the building code, supported by a public or private investors and that they were designed by a highly repetitive pattern of players. In some countries, the private influence was stronger than others, whereas in other countries, the public influence had a stronger role. The main reason for constructing an MTB depends on the wish of the private or public client. In both cases, sustainability was declared as the major reason for the commission. The contextual analysis also revealed other relevant findings. An MTB is generally greatly affected by an R&D program, or influenced by policies created by public actors. It also became evident that there are several players who have a more frequent correlation to MTBs compared to others. These players were identified as major drivers affecting the practice of creating MTBs. They involve a wide range of professionals including architects, engineers, contractors, timber manufacturers, and public and private clients. Additionally, some projects were identified as strongly influential for the other national and international case-studies.

In conclusion, this chapter shows that the role of the regulatory framework and the industry (intended as stakeholders and timber manufactures) are both relevant which was also confirmed by the literature review. Clusters of solutions and patterns of interdependence between stakeholders and case-studies were identified and related to specific drivers. The international trends and the national nuances evidenced in Chapter 5 were the result of the different contextual environments in which each case-study was designed and constructed. In the construction phase, the industry and its availability can play a relevant role, such as in the case of Switzerland, or it can be marginal, like in the case of Australia, where the necessary EWPs were shipped from Europe. In this context, it can be said that timber (intended as EWPs) can be both a local and an international material. However, the design knowledge is still strongly linked to timber engineers, contractors, and suppliers. This resulted in only a few architectural offices being specialised in the design of MTBs, or being capable of influencing the final outcome. All in all, the transfer of knowledge, the positive interaction between public and private actors, along with the relaxed regulatory framework and the role of the industry itself are all important aspects that will contribute to the future success of MTBs.

Chapter 7

Conclusions

This chapter concludes the dissertation by presenting the main findings. The comparative survey conducted in this dissertation provides a better overview of the evolution of worldwide MTB construction. A first section clarifies how this study adds to the existing academic literature on MTBs. Many figures can profit from this research. In addition to academia, many professionals can benefit from the quantitative data collected in this study, and designers can have a better understanding of the spectrum of solutions available to them. An additional section is dedicated to the main findings observed throughout the analysis of the case-studies in the previous chapters. When looking at it from a global perspective, MTBs were a mainly heterogeneous phenomenon, built with different structural categories and mainly formed by hybrid combinations (timber, concrete, and steel). Furthermore, it is possible to recognise some tendencies in the choice of structural and other design characteristics, but these tendencies do not hold true for every country, and nuances in this regard can be detected. In some cases, stakeholders were the drivers behind the differences in the design of MTBs and the cooperation between them often determines how MTBs will evolve. A first glance at the projects in the design phases after the survey period, and of the project completed, confirms several findings observed in this dissertation. When it comes to the involved stakeholders, the case-studies present characteristics which are similar to those observed in this dissertation. The final section suggests possible further research related to the topic and the findings of the work. The overall perspective that emerges from this study includes both the trends and differences in the design of MTBs around the world. Similarly, the context that characterised the projects in each country present similarities and nuances which made it difficult to group the countries in macro-regions of the world.

MTBs are a niche design practice, but they are quickly evolving. The completion trends in several countries suggest that the number of completed projects will rise over the next decade. What this new generation of projects will look like depends largely on the capabilities of designers and the industry in emphasising nuances and solution clusters beyond what was observed in this dissertation.

7.1 Academic Contribution

The analysis carried out in this dissertation is relevant not only because nothing similar had ever been done on such a global scale, but also because it provides a clear view on the contextual phenomenon of the last twenty years of practice regarding MTBs. The various analyses in this dissertation allows researchers and professionals to properly understand the world practice of MTBs. The main findings observed in this dissertation have many advantages for academic research, designers, the industry, and for policymakers. Academically, it provides a list of completed projects which researchers can use for their analysis and comparisons, and organises qualitative and quantitative data on the global landscape of MTB projects. Designers can look at this work and understand the current spectrum of design possibilities, in addition to understanding the major trends and existing nuances in the global timber construction scene. For the industry, this dissertation provides a list of major actors in various countries, quantitative data, and insights on the relationships between the world actors. For the policymakers, it highlights the best performing countries, cities, contexts, and also highlights some strategies in the promotion and support of MTBs according to different tools, including policies, R&D, and economic support.

The premise of this research rested on the fact that literature on comparative studies of MTBs is scarce and currently there is a lack of established academic literature on how to survey these buildings. Starting from the observation that there is a clear heterogeneity in the design of MTBs, the literature references helped to set the research goals and identify the fields of study in which more attention could be given. In order to answer the research questions, this dissertation had to position itself in the literature on MTBs between the established surveys on comparative studies (Holt and Wardle, 2014), (Smith et al., 2015), (CTBUH Journal, 2017), (Salvadori, 2017), (Kuzmanovska et al., 2018). On the other hand, having the goal of identifying drivers and influencers in the design of MTBs, a parallel stream of the literature was followed and discussed (Lattke and Lehmann, 2007) (Mahapatra and Gustavsson, 2009) (Tykkä et al., 2010) (Nord et al., 2011) (Östman and Källsner, 2011) (Riala and Ilola, 2014) (Gosselin et al., 2015) (Toppinen et al., 2019) (Bowyer et al., 2016) (Goodland, 2016) (Lazarevic et al., 2020) (Hurmekoski et al., 2015) (Wiegand, 2019).

The introduction argued in favour of an appropriate term to refer to multi-storey buildings built with a EWPs-based structure. The existing literature is heterogeneous in the definition of these buildings and lacks proper terminology. The design analysis in Chapter 5, in contrast with the most common terms, highlighted that MTBs are mostly hybrid buildings. For this reason, the author believes these buildings should be referred to as *timber-based* buildings.

Chapter 2 re-ordered the main reasons for constructing MTBs. If the life-cycle of these buildings is well managed, thanks to the high amount of EWPs used in their structures, MTBs can contribute to the necessary storage of CO_2 emissions. Timber is also the only construction material with evident health benefits, and this is an aspect that deserves much more attention.

Chapter 3 reorganised the evolution of EWPs under a different perspective which, to the author's knowledge, was not previously present in the literature. The historical analysis clarified how it was possible to design such tall structures with timber. The current EWPs are a combination of old and new products, and they had different developments. Many key actors were located in Germany and Austria, and this is in part why the EWP industry is strong in both of these countries. However, EWP manufacturers are now located all over the world and there are areas where EWPs prevail over other EWPs (like LVL in New Zealand). In any case, EWPs are the most necessary tool to create the structure of MTBs. The local availability of EWPs had an effect on projects, like in Switzerland, where predominantly local EWPs were used. On the contrary, this study showed that case-studies in Australia were much less dependent on the local timber production, and relied on EWPs produced in other continents.

The central part of the research began in Chapter 4. The survey criteria set by the author allowed this dissertation to obtain an encompassing list of the majority of the MTBs discussed in academic and grey literature combined, in addition to other sources such as online databases. The selected studies were identified in 18 different countries, and the vast majority of them belong to the OECD area. The majority of the case-studies were also completed in the final years of the survey, 2016-2019, concluding that MTBs are a recent and developing type of building.

The design analysis in Chapter 5 added many findings to the academic discussion. First, it provided the largest overview of the world practice, with the comparison of several structural systems between the case-studies of each country. MTBs are not a similar practice everywhere, and an MTB built in Austria, for example, is structurally different from one built in the US. This is a considerable difference compared to other building materials. Furthermore, while the macro-regions identified by the literature showed general trends, national, and in some countries, regional, nuances were also observed. This makes it difficult to categorise these buildings as common regional practices. On the basis of the small amount of existing structural categories in which MTBs were described by the literature, this dissertation proposed a new structural categorisation. Starting from the existing categories, the author added more heterogeneous categories in order to properly describe the different structures of the completed MTBs. Thirty-two categories were identified, and most of them emphasise the relationships between hybrid combinations. Chapter 5 also contains a set of categories of analysis for MTBs that are also based on the existing literature but have been enriched by the author. In this regard, an MTB can have a wide range of storeys, dimensions, and number of buildings. Through the analysis of the case-studies under these different aspects, several countries emerged as forerunners in the development of MTBs.

The differences and commonalities observed in the design analysis were further investigated in Chapter 6 with the analysis of the context of each case-study. Through the analysis of the influences, motivations and the stakeholders involved in each case-study, Chapter 6 not only clarifies most of the clusters of design solutions observed in the previous chapter, but also enriched the literature by providing qualitative and quantitative data on the public and private overall influences in the case studies and their main motivations. Some major drivers of design solutions emerged in

this study. They can be a city, designer or timber manufacturer, and they all contribute in different ways to the construction of MTBs. MTBs are mostly financed by private investors with high sustainability targets for their buildings. There were some countries where the public influence was more predominant than others. Several cities from the case-studies in this dissertation appear to be most favourable for MTBs and the dissertation pointed to the recurrences of the stakeholders involved. The role of timber engineering in particular was brought forth, as several countries saw the majority of their projects being designed by the same few timber engineering offices. While Chapter 5 showed the heterogeneous practices of designing MTBs, along with local nuances and specific solutions applied in some outstanding examples, Chapter 6 showed that MTBs are still a niche practice, especially when it comes to timber engineering and timber supply. Regarding the supply of timber, it can be both a local material with nationally and regionally unique practices, but it can also be an international product. Many case-studies were supplied by a timber manufacturer in other countries, or even in other continents. In this regard, Austria emerged as the leading place for the production of the EWPs used in the selected case-studies.

All in all, MTBs emerged as a complex practice with different clusters of solutions. These clusters were sometimes suggested by other literature, but they had never been highlighted in the way they were in this study. The future MTBs will in part stem from these technical solutions observed and described in this thesis.

7.2 The Phenomenon of MTBs

Below are the main findings observed throughout the analysis of the case studies in the previous chapters. Some were addressed throughout the thesis, meanwhile others are summarised here for the first time.

National differences of MTBs

This dissertation presented the manifested nuances of the design, construction, and context of MTBs. It was possible to highlight trends in the design which were trans-national, but at the same time the findings of this thesis also pointed out evident national, and in some cases regional, differences, seldom evidenced by the literature. While the regulatory framework played a relevant role, these national and regional differences were not always determined by it. This dissertation made the connection between these differences and the relationships and influence the stakeholders had on the case-studies, which revealed that, in some cases, the stakeholders were the real driver behind the design properties of MTBs. Additionally, many MTBs were financed by private investors, which in some countries can be considered the true drivers of the projects. Sometimes the technical solutions chosen by the architect affected the design, other times it was the wish of a developer that had a similar effect. In other cases it was the timber supplier who proposed collaboration with a public company, a structural system which in turn characterised the majority of the case-studies in the country.

Structural categorisation and cluster of solutions

This study demonstrated the various ways in which MTBs can be designed. Until the present day, a complete overview of the phenomenon of MTBs has never been published. The few examples compared in the previous study suggested that MTBs might have been designed in different ways, but not enough buildings were compared side by side for this to be confirmed. By comparing 197 international case-studies, this dissertation filled a gap in the literature. The list created here can be enriched by further studies, or can be used to deeply analyse other themes in the construction of MTBs. Through the introduction of 32 structural categories defining the structure of the analysed case studies, it was possible to highlight specific practices which were then related to specific R&D programs, an architectural office, or a contractor's expertise. However, the majority of the projects can be organized into six categories, with most of them designed as panelised timber-concrete and post-and-beam timber concrete. The structural categories introduced also allowed this thesis to highlight a cluster of national or world region solutions. There are some technical solutions in the design of MTBs which can only be seen in some countries. Examples of this include the Norwegian case-studies *Mjøstårnet* and *Treet* which have a unique structural system based on an R&D called "Trä8". Another cluster of solutions was observed in Germany with the projects designed by Kaden-Lager Architekten. Overall, these clusters are formed by few buildings, but they may represent a new stream of future projects with shared and unique technical solutions, contributing to making MTBs a national or even local phenomenon.

Hybrid structures

The design analysis also proved that in reality, MTBs are indeed *timber-based* buildings in the vast majority of the selected case-studies. An all-timber structure was rare, and still is in the most recent examples. Concrete podiums, and concrete or steel cores, together with different steel structural elements, were all used in combinations with a timber structure. Calling these buildings just "timber buildings" is therefore incorrect. There are several reasons for these hybridisations. Oftentimes, the strict regulatory framework obliged designers to plan the structure with a concrete core for escape routes such as in Austria, Germany, and Switzerland. In other situations, concrete and steel were used to give the necessary stiffening to the structure. In other examples, a concrete podium allowed the building to have a more flexible floor, which is traditionally used for other types of functions, such as in shops or restaurants. Concrete makes the building cheaper, and makes the floor slabs thinner and heavier. The latter has significant implications. Therefore, hybridisation between timber with concrete and steel is not always an obligation dictated by the regulatory framework.

The constructive materials of MTBs

The design analysis was also enriched by other categories of analysis, through the study of other structural aspects. This additional analysis allowed this research to evidence trends in the use of concrete and CLT. The latter in particular is the EWP that is most predominantly used around the world. Only the US and Switzerland have fewer case-studies which used CLT. In Chapter 3 of this dissertation the history of the development of CLT was described, and the reasons for

its success were revealed. The design analysis also showed that the structure of an MTB can be composed of several EWPs. There are only a few countries, such as the United Kingdom, Italy, Norway and Spain, where the majority of the case-studies were built with a structure primarily formed by CLT walls, floor slabs, and core. The dissertation provided examples in which EWPs can also be combined, such as in *Bjergsted Financial Park*.

Program, appearance and building volumes

Trends were also observed in the analysis of other design aspects. For example, MTBs are mainly residential buildings, but in some countries like the US or France, the majority of the buildings were offices. In Norway, the majority of the case-studies were student housing. Similar trends and nuances were observed in other analysed categories like external cladding and timber exposure. An MTB does not always look like a timber building from the outside. While the majority of the case-studies in Scandinavia and in Germany have a wooden facade, in many other countries the majority of the projects were enveloped by other materials like metal and plaster. In the UK in particular, the vast majority of the case-studies had a brick facade. The timber exposure inside the MTBs analysed in this study varies, and largely depended on the regulatory framework of a country. With an appropriate fire strategy, strict rules could be overcome, but this often led to higher costs which were not always agreed upon. In general, the trend observed in this regard is the preference for exposing the timber structure partially, such as on ceilings or walls. There are also countries in which the structure of the buildings is commonly exposed, such as in the US, and countries where the structure is nearly always enveloped in gypsum boards, such as in Italy and the United Kingdom. No particular differences were observed in the architectural mass of these buildings, which are designed with regular plans and volumes in every country. Only a handful of projects show a different approach. Examples are the buildings composed using an assembly kit or 3D modules, which attempt to combine off-site construction and architectural expression in one concept. It is clear that these projects focused on the technical challenges of their structures and had to navigate regulatory framework and other related issues. More complex architecture will only be possible once architects will gain more control of the design of these buildings.

Importance and role of the stakeholders

This thesis demonstrated that the role played by stakeholders and the context in which MTBs are designed and constructed is not secondary, and in some cases these can affect the design of an MTB with the same amount of influence as the regulatory framework. With projects like *Cenni di Cambiamento* or *Wood Innovation Centre*, the regulatory framework was modified according to the projects, and this was initiated by their stakeholders. Additionally, EWPs proved to be international products and timber manufacturers supplied projects in different continents. The example of Australia demonstrated that a country can build MTBs even without a strong EWP supplier industry. All the Australian case-studies were indeed supplied by European timber manufacturers. Private investors were the majority of the clients of these buildings, and their wish to build sustainable projects led to realisation of some of the tallest and most representative projects like *HoHo Wien* and *Mjøstårnet*. Additionally, many cities and countries influenced the realisation

of these buildings. Examples of these are Vienna, Växjö, and the Hackney Council which, thanks to direct or indirect strategies, prepared a positive environment for the realisation of MTBs in their areas. Sustainability was the main reason why the selected case-studies were realised. The contextual analysis revealed the repetition of several stakeholders involved in the design and construction of many of the selected MTBs. Particularly high rates of repetition were observed in the timber engineers, contractors, and timber suppliers. This suggests that MTBs are still a niche topic in the majority of the countries analysed. The case-studies in countries with some of the highest number of MTBs, such as the United Kingdom and Austria, were mainly designed by two or three major engineering offices. In general, architects of these projects tend to be less repetitive than other professionals involved. However, in countries such as the United Kingdom, Austria and Germany, architects were more frequently involved, and in some cases even strongly influenced the final design and construction. Similar considerations can be made for both the general and timber contractors. The general trend shows that the same several companies are involved in the case studies, and in Norway and the United Kingdom, the majority of the case-studies were constructed by just one or two general contractors or timber contractors. Similar findings were observed in the analysis of the timber supply of these projects. EWPs proved to be both local and international. While the majority of the countries relied on local producers for the EWPs necessary for their MTB structure, it is also true that many case-studies were supplied by foreign companies. In the latter case, Austrian companies were the most common supplier. The second most prevalent supplier was Stora Enso, a Finnish-Swedish company which produces its CLT panels in Austria. With this considered, more than half of the case-studies were supplied by EWPs produced in Austria.

The dilemma of MTBs: globalised or local constructive practice?

This study presented the state of the art of MTBs from the last twenty years of practice under a constructive and contextual analysis. The outcome presented MTBs as a complex and heterogeneous phenomenon, which makes it difficult to include in macro-regions. There are even differences within countries as to how these buildings are built. In light of these findings, it is worth considering if MTBs should become a globalised and similar practice around the world, or if these regional differences should be promoted. The answer to this question might have different repercussions on the evolution of MTB and their industry. The many nuances in the ways these buildings are built, in the author's opinion, are of considerable uniqueness in the building materials' scenario. Concrete and steel structures are in fact similar all over the world, and it is not possible to recognise the difference if a building is completed in Asia or in Europe. The geographical differences of MTBs are therefore a characteristic which should be emphasised and encouraged. However, it is also true that a more standardised system might also make MTBs much more common. In light of the current environmental situation, the latter is desirable. It is also plausible that both scenarios will happen, with large construction companies producing standardised timber buildings, and others specialising in tailor-made elements which can be an expression of local or regional knowledge. What is clear today is that MTBs are still a niche topic in timber engineering and construction, and only education and the important transfer of know-how will solve the increasing demand for professionals and new technical solutions.

7.3 Beyond 2019

Due to reasons of feasibility, the survey conducted in this dissertation ends with the year 2019. However, after 2019 other relevant projects were under construction or completed. By a brief analysis of some projects, the findings and the relationships observed in this work continues to exist. In Europe, several projects were completed by stakeholders frequently observed in this survey. In Germany, Merz Klay is engineering the project *Woodscraper*, and in Berlin, *Südkreuz* office is constructed using the CREE system (Cree Buildings, n.d.). The office White Architects is involved in the design of two representative Swedish projects of *Skellefteås Kulturhus* and *Växjö City Hall*. *Skellefteås kulturhus* is a tower under construction in Skellefteå which was supplied by Martinsons (White Arkitekter, n.d.*b*). The project *Växjö City Hall* is also under construction after the jury of an architectural competition assigned the project to White Architects. *Växjö City Hall* houses the offices of the city of Växjö, adding up to the long list of MTBs of the city (White Arkitekter, n.d.*c*). Additionally, the second building of the *Wood City* development was completed in Finland. The office is designed with the Stora Enso LVL-based system (Hernández, 2018). Both Arup and the Woschitz Group were involved in the engineering of *Haut* in the Netherlands. They engineered the hybrid post-and-beam timber-concrete-steel structure of the tower (Woschitz Group, n.d.).

Figure 7.1: Woodscarper, Skellefteås Kulturhus, and Haut

Source: Partner und partner architekten, White arkitekter, Haut Amsterdam

In North America, several projects follow the trend of using a post-and-beam structure for offices. For example, the project *Catalyst* was completed by Katerra, a construction company founded in 2015, which purchased both the Canadian companies, Equilibrium and Michael Green (Keane and Lau, 2018). All of these offices were involved in the design of *Catalyst*, which has a post-and-beam structure and is located in Spokane (USA). CLT is used in the floor slabs. As observed in the American case-studies, the floor slabs shifted from NLT to CLT, and *Catalyst* seems to confirm the move towards CLT in the industry. The choice of using CLT was favoured by the fact that Katerra produces the product (Alexander Walter, 2021). In Canada, *Arbour*, is designed by Moriyama & Teshima Architects and Acton Ostry Architects (Acton Ostry Architects, n.d.). The latter

Figure 7.2: Catalyst and the Arbour

Source: Benjamin Benschneider, Moriyama & Teshima Architects

designed *UBC Brock Commons*. According to Wiegand (2019), *Arbour "(...) was also influenced by the Brock Commons, particularly in regard to its construction system and fabrication process."* Another building, *Terrace House* is designed by Shigeru Ban, which was involved in the Swiss case-studies *Tamedia Office* and *Omega Headquarters* (Eleanor Gibson, 2017). Both the projects continues the trend of hybrid post-and-beam structures in Canada.

In Australia, the project *La Trobe University Student Accommodation* was completed in 2020 and was supplied by the Italian Xlam Dolomiti which again partnered with Multiplex, the same company which built *Gilles Hall* (Eco Voice, 2020). In Japan, the Sumitomo Forestry committed building the tallest proposed timber building by 2041, which is the 350th anniversary of the foundation of the company. In order to reach this goal, the company is planning a series of smaller buildings in order to achieve the ambitious project of this timber skyscraper (Lynch, 2018).

All of these new projects confirm the repetition of several key design characteristics and stakeholders observed in this dissertation.

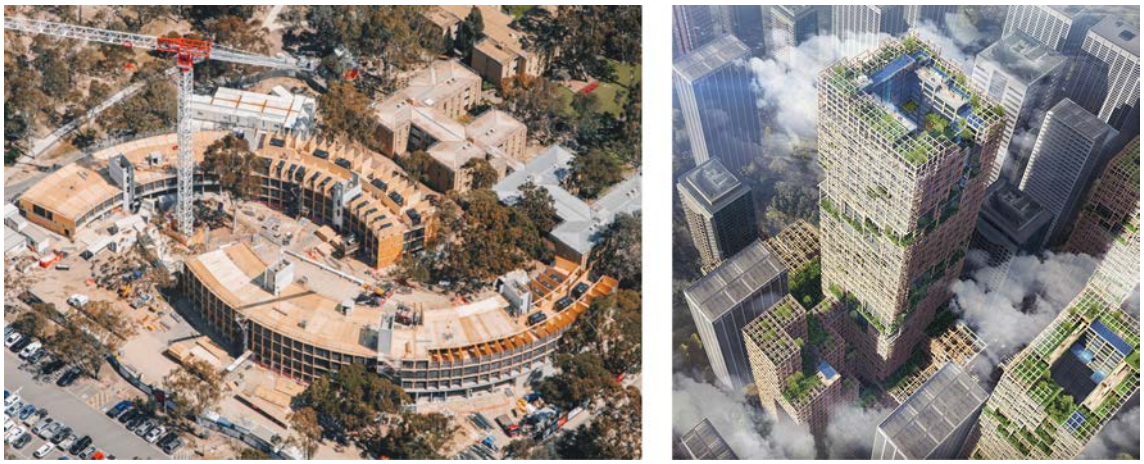

Figure 7.3: La Trobe University Student Accommodation and W350 Project

Source: Multiplex and Sumitomo Forestry Co.

7.4 Potential Avenues for Further Research

The following section proposes several paths for further research in the field of MTBs. Some suggestions were already given in the course of the thesis, and are restated here.

Education and Promotion

MTBs are a complex topic, and this dissertation showed that they are quickly evolving. The repetition of some professionals and companies means that a high level of knowledge is a prerequisite for the successful delivery of an MTB. This is why education at all levels (architects, engineers, timber production, timber construction) must be strengthened and improved. Only by having more skilled professionals, with an in-depth knowledge on the state of the art and its technical developments, will timber construction be able to face the rising demand of sustainable buildings.

The design role of architects

What is the design role of architects in MTBs? As was observed in Chapter 6, the patterns of repetition regarding architects are lower than other professionals. MTBs are primarily an engineering challenge, and it is possible to consider that engineers have a stronger say in the design of these buildings. This is a hypothesis, and needs further investigation. Further studies which focus on the influences that architects have on the design of an MTB are necessary, particularly in understanding of the lack of knowledge that architects have. The analysis of the building volumes showed that MTBs are formed by simple volumes, and very few case studies were, from an architectural point of view, complex structures. This could also be an area in which architects can positively influence new solutions, but in order to do so, they need a deeper understanding of the topic.

Timber companies and off-site prefabrication

The analysis of the contractors and timber suppliers highlighted the fact that heterogeneous types of companies were involved in the construction and supply of the case-studies. Some companies like Veidekke are big construction companies, others are more local, with fewer but highly trained workers, especially in the Central Europe area. Some companies like Erne, are building hybrid components, whereas others like Katerra, are more focused on all-timber construction. Which companies are better fit to solve the challenges of building with timber? Is hybrid construction a business advantage, or even a necessary transition for an established company? The design analysis highlighted several assembly practices that can be better described in dedicated studies. There are several degrees of prefabrication, and there are many companies that can guarantee many off-site solutions. If the global trend is to pre-assemble the parts before arriving at the building site, it would be interesting to study the specific technical, logistic, and cost competitive solutions used by the most innovative companies.

BIM and the design of MTBs

MTBs are also the result of a lot of professionals expertise and coordination. Logistic and assembly were proved to be better managed with BIM programs, and the taller and complex MTBs will

become, the more coordination and sharing information will result vital in the successful delivery. Comparative studies and research on how professionals managed such innovative projects, and the implications in the design process will be necessary to investigate the knowledge that is focused on the on-site part of the construction of these buildings.

Timber, MTBs, and effective policies

The analysis of the context performed in Chapter 6 highlighted the role that some policies played in influencing the design and realisation of several MTBs. In light of the 2050 decarbonisation targets and goals by institutions at all levels, a wider study of the influences that policies have on the promotion, and financing of MTBs is advisable along with the potential of timber for these decarbonisation targets.

Market focus on China, India and Japan

The present research included many case-studies which were built mainly in Europe and North America. There is very little data available online regarding MTBs in China, India, and Japan, all Asian countries which have powerful and demanding markets. Studies on possible strategies to tackle their current and future demand for sustainable buildings with timber would be a valuable insight to complete the global perspective on MTBs. Given their high-density area, MTBs will be a possible solution.

Updated case-studies after 2019

This dissertation researched the majority of the MTBs completed between 2004 and 2019. The study of the evolution of the coming years will be a necessary path to follow. Will the trends and nuances that this thesis emphasised continue, or will MTBs become a homogeneous practice similar to concrete and steel? Key to answering this question will be the research of the influence of the stakeholders as done in this dissertation, which can be used as a starting point and then enriched, or focused on in greater detail. In addition, new players will join the field, and it will be interesting to understand in what way these future players affect the design of these buildings.

Evolution of the use and the production of EWPs

In parallel to the professional's involvement, it would be interesting to continue to observe the use of EWPs, especially to see if the influence of LVL will grow, and if new construction concepts based on combination of timber and other materials, or combinations of several EWPs together, reach new developments. This dissertation showed that the leading role in the EWPs manufacturing is played by Austria, especially in CLT production. This is because the mass production and the technological development of CLT started in Austria at the start of the 2000s. New CLT plants are opening all over the globe. As a result, several questions emerge. Is the CLT produced in other countries similar to the one made in Austria? Can CLT be locally-influenced by the type of timber available in the area, and in what way can this will influence the final product? These and similar questions can be made for the other EWPs products as well. As explained in Chapter 3, some EWPs are recent products, and as MTBs evolve, these do as well.

Fire, building physics and acoustic

One of the main contributions of this dissertation is its creation of an encompassing list of MTBs around the world. There are several design aspects which could be researched further, now that this list and the design description of the case-studies are available. Fire strategies and their national evolution, building physics and acoustics, together with moisture strategies, were considered top concerns in several case-studies examined for this dissertation. A catalogue of detailed solutions could be a relevant addendum to the existing literature on the topic.

7.5 Concluding Remarks

This study provided information and data on how MTBs could be designed. Sharing this knowledge with as many designers as possible was the ultimate goal of this entire work. If designers can see what other professionals are doing, then they can improve, change, or sharpen their ideas and thoughts in regard to these buildings. The objective was not to promote uniformity, but to present the state of the art of these buildings as they are, a heterogeneous phenomenon which needed to be presented with a global perspective. Timber in tall structures was the result of a long process which already began in the 20^{th} century with the development of glulam. Technological advancement and new machinery always led to new innovations in the way carpenters and companies erected timber structures. Parallel to these innovations, bright minds explored new paths and proposed technical solutions both in private fields or in academia. These patterns are still happening and many timber companies and stakeholders that were identified in this thesis are bringing the timber industry from a niche phenomenon to a more globalised one. Realizing an MTB involves, like any other building, local authorities, clients, developers, architects, engineers, consultants, timber producers and timber contractors/erectors, all of whom create a network of relationships. The value of these relationships is a vital aspect for the flourishing of these types of structures. The future evolution of these relationships could lead to a more homogeneous construction, or on the contrary, to several "schools" of practice, recognisable by their designs, concepts, EWPs, and technical solutions used. In the author's opinion, these differences must be emphasised and maintained if we want to add "local aspects" to the list of pros regarding timber construction. It is possible that both scenarios will happen and MTBs will become available for everyone, and highly skilled practices will still compete locally and globally for the highest standards.

Finally, this study provided the first step towards identifying trends, commonalities and differences which shed light on how MTBs are evolving. Beside these considerations, this dissertation had the goal of being a starting point for further research. MTBs are a constructive phenomenon which are part of a broader pattern of relationships between government, professionals and industries and which has become more and more relevant in recent years. In light of the necessity to decarbonise and build buildings which store CO_2, along with the capacities of the market and industry, academic research on these buildings will be worthwhile and necessary in order to better facilitate their realisation.

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Appendix A

Case-studies

In this Appendix the 197 case-studies each have a one-page description where the main data are collected.

- **Austria**: Pages 305-320
- **Benelux**: Pages 322-326
- **Finland**: Pages 328-337
- **France**: Pages 339-357
- **Germany**: Pages 359-377
- **Italy**: Pages 379-391
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- **United Kingdom**: Pages 456-478
- **Canada**: Pages 480-489
- **United States**: Pages 491-504
- **Australia**: Pages 506-514
- **Other Countries**: Pages 516-518

A.1 Austria

Project (name)	(image)	Storeys (number)	Timber Storeys (number)	Structutral system (logo)	(category)	Core (material)	Floor Slabs (material)	Total Built Surface (m2)	Program (type)	Facade cladding (material)	Structural timber exposure (category)
Spöttlgasse		5	4		Panelised timber-concrete (podium-core)	Concrete	CLT	5300	Residential - Social Housing	Plaster	None
Mühlweg Bauteil C		5	5		Panelised timber-concrete (core)	Concrete	CLT	6750	Residential - Social Housing	Plaster	None
BMW-Hotel Alpenhof		5	3		3D Modular timber-concrete (podium-core)	Concrete	CLT	8175	Hotel	Metal	All the surfaces
Life Cycle Tower		8	7		Post-and-Beam timber-concrete (podium-core)	Concrete	Glulam-concrete	2300	Office	Metal	All the surfaces
Senioren wohnheim Hallein		5	4		3D Modular timber-concrete (podium-core)	Concrete	CLT	10218	Senior living	Metal	Ceiling
Wagramerstrasse		7	6		Panelised timber-concrete (podium-core)	Concrete	CLT-concrete	6254	Residential - Social Housing	Plaster	None
Illwerke Zentrum Montafon		5	5		Post-and-Beam timber-concrete (core)	Concrete	Glulam-concrete	11500	Office	Wood	All the surfaces
Reininghaus Sud		5	4		Panelised timber-concrete (podium-core)	Concrete	CLT	4000	Residential	Plaster	Ceiling
Holzwohnbau Rosenstraße		5	4		Panelised timber-concrete (podium-core)	Concrete	CLT	2265	Residential	Cement based	Ceiling
Hummelkaserne		6	6		Panelised timber-concrete (core)	Concrete	CLT	9306	Residential	Wood	None
Mineroom		5	5		Panelised timber-concrete (core)	Concrete	CLT	5274	Student Housing	Wood	Ceiling
Holzwohnbauten im Dragoner-Quartier		6	6		Panelised timber-concrete (core)	Concrete	CLT	1875	Residential	Wood	Ceiling
Hoho Next		6	6		Post-and-Beam timber-concrete (core)	Concrete	CLT-concrete	5686	Office	Wood	All the surfaces
Gesundheits. Quartiers		7	6		Panelised timber-concrete (podium-core)	Concrete	CLT-concrete	3585	Residential	Wood	Ceiling
Gleis 21		6	5		Panelised timber-concrete (podium-core)	Concrete	CLT-concrete	3992	Residential - Co-housing	Wood	All the surfaces
Hoho Wien		24	24		Post-and-Beam timber-concrete (core)	Concrete	CLT-concrete	25000	Mixed Use (residential-other)	Cement based	All the surfaces

Spöttlgasse

Year Completation	2004
Country	Austria
City	Vienna
Number of Storeys	5
Number Timber Storeys	4

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	5300
Total surface built (f²)	57049
Structural category	Panelised timber-concrete (podium-core)
Podium	Ground Floor
Core	Concrete
Floor slabs	CLT
Program	Residential - Social Housing
External Cladding	Plaster
Indoor elements exposed	All the elements
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Public
Motivations	Sustainability
Architect	Hubert Riess, AT
Engineer	JR Consult , AT
Timber Engineer	Woschitz Group, AT
General Contractor	Kulmer Holzleimbau, AT
Timber Contractor	Kulmer Holzleimbau, AT
Timber Supplier:	
Structural Elements	KLH, AT
Floor Elements	KLH, AT
Client	Sozialbau AG, AT

SOURCE OF IMAGES

Sozialbau AG, Woschitz Group, KLH

Wohnsiedlung Mühlweg Bauteil C

Year Completation	2006
Country	Austria
City	Vienna
Number of Storeys	5
Number Timber Storeys	5

DESIGN DATA

Number of Buildings	4
Total surface built (m²)	6750
Total surface built (f²)	72657
Structural category	Panelised timber-concrete (core)
Podium	None
Core	Concrete
Floor slabs	CLT
Program	Residential - Social Housing
External Cladding	Plaster
Indoor elements exposed	None
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Competition
Influence	Public
Motivations	Sustainability
Architect	Dietrich Untertrifaller Architekten, AT
Engineer	JR Consult , AT
Timber Engineer	KLH, AT
General Contractor	Kulmer Holzleimbau, AT
Timber Contractor	Kulmer Holzleimbau, AT
Timber Supplier:	
Structural Elements	KLH, AT
Floor Elements	KLH, AT
Client	BAI Bauträger Austria Immobilien, AT

SOURCE OF IMAGES

Bruno Klomfar, Martina Nöstler, KLH

BMW-Hotel Alpenhof

Year Completation	2009
Country	Austria
City	Reutte
Number of Storeys	5
Number Timber Storeys	3

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	8175
Total surface built (f²)	87996
Structural category	3D Modular timber-concrete (podium-core)
Podium	Up to first floor
Core	Concrete
Floor slabs	CLT
Program	Hotel
External Cladding	Metal
Indoor elements exposed	All the surfaces
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Competition
Influence	Private
Motivations	Technical aspects
Architect	Oskar Leo Kaufmann - Albert Rüf, AT
Engineer	Mader & Flatz, AT
Timber Engineer	Merz Kley Partners, AT
General Contractor	Kaufmann Bausysteme, AT
Timber Contractor	Kaufmann Bausysteme, AT
Timber Supplier:	
Structural Elements	KLH, AT
Floor Elements	KLH, AT
Client	BMW Group, DE

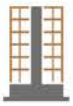
SOURCE OF IMAGES

Booking, Kaufmann Bausysteme

Life Cycle Tower

Year Completation	2012
Country	Austria
City	Dornbirn
Number of Storeys	8
Number Timber Storeys	7

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	2300
Total surface built (f²)	24757
Structural category	 Post-and-Beam timber-concrete (podium-core)
Podium	Ground Floor
Core	Concrete
Floor slabs	Glulam-concrete
Program	Office
External Cladding	Metal
Indoor elements exposed	All the surfaces
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Public/Private
Motivations	Technical aspects
Architect	Hermann Kaufmann Architekten, AT
Engineer	Merz Kley Partners, AT
Timber Engineer	Merz Kley Partners, AT
General Contractor	CREE Rhomberg, AT
Timber Contractor	Sohm Holzabutechnick, AT
Timber Supplier:	
Structural Elements	Wiehag, AT
Floor Elements	Wiehag, AT
Client	CREE Rhomberg, AT

SOURCE OF IMAGES

Cree by Rhomberg, Hermann Kaufmann

Seniorenwohnheim

Year Completation	2013
Country	Austria
City	Hallein
Number of Storeys	5
Number Timber Storeys	4

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	10218
Total surface built (f²)	109987
Structural category	3D Modular timber-concrete (podium-core)
Podium	Ground Floor
Core	Concrete
Floor slabs	CLT
Program	Senior living
External Cladding	Metal
Indoor elements exposed	Ceiling
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Competition
Influence	Public
Motivations	Building erection speed
Architect	SPS Architekten, AT
Engineer	Merz Kley Partners, AT
Timber Engineer	Kaufmann Bausysteme, AT
General Contractor	Kaufmann Bausysteme, AT
Timber Contractor	Kaufmann Bausysteme, AT
Timber Supplier:	
Structural Elements	Mayr-Melnhof Holz, AT
Floor Elements	Mayr-Melnhof Holz, AT
Client	Stadtgemeinde Hallein, AT

SOURCE OF IMAGES

Kaufmann Bausysteme

Wagramerstrasse

Year Completation	2013
Country	Austria
City	Vienna
Number of Storeys	7
Number Timber Storeys	6

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	6254
Total surface built (f²)	67318
Structural category	Panelised timber-concrete (podium-core)
Podium	Ground Floor
Core	Concrete
Floor slabs	CLT-concrete
Program	Residential - Social Housing
External Cladding	Plaster
Indoor elements exposed	None
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Competition
Influence	Private
Motivations	Sustainability
Architect	Schluder Hagmüller Architekten, AT
Engineer	Woschitz Group, AT
Timber Engineer	Woschitz Group, AT
General Contractor	Voitl & Co, AT
Timber Contractor	Aichinger Hoch-, Tief-, Holzbau, AT
Timber Supplier:	
Structural Elements	Binderholz, AT
Floor Elements	Binderholz, AT
Client	Familie, Gemeinnützige, AT

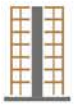
SOURCE OF IMAGES

Bruno Klomfar, Competitiononline, proHolz Austria

Illwerke Zentrum Montafon

Year Completation	2014
Country	Austria
City	Vandans
Number of Storeys	5
Number Timber Storeys	5

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	11500
Total surface built (f²)	123786
Structural category	 Post-and-Beam timber-concrete (core)
Podium	None
Core	Concrete
Floor slabs	Glulam-concrete
Program	Office
External Cladding	Wood
Indoor elements exposed	All the surfaces
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Competition
Influence	Private
Motivations	Technical aspects
Architect	Hermann Kaufmann Architekten, AT
Engineer	Merz Kley Partners, AT
Timber Engineer	Merz Kley Partners, AT
General Contractor	CREE Rhomberg, AT
Timber Contractor	CREE Rhomberg, AT
Timber Supplier:	
Structural Elements	Mayr-Melnhof Holz, AT
Floor Elements	Mayr-Melnhof Holz, AT
Client	Vorarlberger Illwerke, AT

SOURCE OF IMAGES

Bruno Klomfar, Norman Radon, Hermann Kaufmann Architekten

Reininghaus Sud

Year Completation	2015
Country	Austria
City	Graz
Number of Storeys	5
Number Timber Storeys	4

DESIGN DATA

Number of Buildings	2
Total surface built (m²)	4000
Total surface built (f²)	43056
Structural category	Panelised timber-concrete (podium-core)
Podium	Ground Floor
Core	Concrete
Floor slabs	CLT
Program	Residential
External Cladding	Plaster
Indoor elements exposed	Ceiling
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Competition
Influence	Public
Motivations	Sustainability
Architect	Nussmüller Architekten, AT
Engineer	Kulm Bau, AT
Timber Engineer	Kulm Bau, AT
General Contractor	Kulmer Holzleimbau, AT
Timber Contractor	Kulmer Holzleimbau, AT
Timber Supplier:	
Structural Elements	Stora Enso, FI, SE
Floor Elements	Stora Enso, FI, SE
Client	Aktiv Klimahaus WeGraz, AT

SOURCE OF IMAGES

Paul Ott, proHolz Austria

Holzwohnbau Rosenstraße

Year Completation	2016
Country	Austria
City	Linz
Number of Storeys	5
Number Timber Storeys	4

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	2265
Total surface built (f²)	24380
Structural category	Panelised timber-concrete (podium-core)
Podium	Ground Floor
Core	Concrete
Floor slabs	CLT
Program	Residential
External Cladding	Cement based
Indoor elements exposed	Ceiling
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Public
Motivations	Sustainability
Architect	X Architekten, AT
Engineer	TRIAX, AT
Timber Engineer	Brüder Resch, AT
General Contractor	Brüder Resch, AT
Timber Contractor	Brüder Resch, AT
Timber Supplier:	
Structural Elements	KLH, AT
Floor Elements	KLH, AT
Client	Diözesane Immobilien-Stiftung, AT

SOURCE OF IMAGES

X Architekten, KLH

Hummelkaserne

Year Completation	2016
Country	Austria
City	Graz
Number of Storeys	6
Number Timber Storeys	6

DESIGN DATA

Number of Buildings	4
Total surface built (m²)	9306
Total surface built (f²)	100170
Structural category	Panelised timber-concrete (core)
Podium	None
Core	Concrete
Floor slabs	CLT
Program	Residential
External Cladding	Wood
Indoor elements exposed	None
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Competition
Influence	Public
Motivations	Sustainability
Architect	SPS Architekten, AT
Engineer	Merz Kley Partners, AT
Timber Engineer	Merz Kley Partners, AT
General Contractor	Kaufmann Bausysteme, AT
Timber Contractor	Kulmer Holzleimbau, AT
Timber Supplier:	
Structural Elements	Mayr-Melnhof Holz, AT
Floor Elements	Mayr-Melnhof Holz, AT
Client	ENW – Gemeinnützige Wohnungsgesellschaft, AT

SOURCE OF IMAGES

Holzistgenial.at, Paul Ott

Mineroom

Year Completation	2016
Country	Austria
City	Leoben
Number of Storeys	5
Number Timber Storeys	5

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	5274
Total surface built (f²)	56769
Structural category	Panelised timber-concrete (core)
Podium	None
Core	Concrete
Floor slabs	CLT
Program	Student Housing
External Cladding	Wood
Indoor elements exposed	Ceiling
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Competition
Influence	Public
Motivations	Building erection speed
Architect	aap.architekten, AT
Engineer	Kurt Pock, AT
Timber Engineer	n/a
General Contractor	Swietelsky, AT
Timber Contractor	Weissenseer Holz-System-Bau, AT
Timber Supplier:	
Structural Elements	KLH, AT
Floor Elements	KLH, AT
Client	Wohn und Siedlungsgenossenschaft Ennstal, AT

SOURCE OF IMAGES

J.Konstantinov, Weissenseer

Holzwohnbauten im Dragoner-Quartier

Year Completation	2017
Country	Austria
City	Wels
Number of Storeys	6
Number Timber Storeys	6

DESIGN DATA

Number of Buildings	2
Total surface built (m²)	1875
Total surface built (f²)	20183
Structural category	Panelised timber-concrete (core)
Podium	None
Core	Concrete
Floor slabs	CLT
Program	Residential
External Cladding	Wood
Indoor elements exposed	Ceiling
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Competition
Influence	Public/Private
Motivations	Sustainability
Architect	Luger und Maul, AT
Engineer	Obermayr Holzkonstruktionen, AT
Timber Engineer	Obermayr Holzkonstruktionen, AT
General Contractor	Obermayr Holzkonstruktionen, AT
Timber Contractor	Obermayr Holzkonstruktionen, AT
Timber Supplier:	
Structural Elements	n/a
Floor Elements	n/a
Client	WAG Wohnungsanlagen, AT

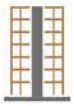
SOURCE OF IMAGES

Walter Ebenhofer, Obermayr Holzkonstruktionen

Hoho Next

Year Completation	2018
Country	Austria
City	Vienna
Number of Storeys	6
Number Timber Storeys	6

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	5686
Total surface built (f²)	61204
Structural category	 Post-and-Beam timber-concrete (core)
Podium	None
Core	Concrete
Floor slabs	CLT-concrete
Program	Office
External Cladding	Wood
Indoor elements exposed	All the surfaces
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Sustainability
Architect	Rudiger Leiner Architekten, AT
Engineer	Woschitz Group, AT
Timber Engineer	Woschitz Group, AT
General Contractor	Handler, AT
Timber Contractor	Handler, AT
Timber Supplier:	
Structural Elements	Hasslacher Nordica Timber, AT
Floor Elements	XlamConcrete, AT
Client	Cetus Baudevelopment, AT

SOURCE OF IMAGES

cetus Baudevelopment, Kito

Gesundheits.Quartiers

Year Completation	2019
Country	Austria
City	Vienna
Number of Storeys	7
Number Timber Storeys	6

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	3585
Total surface built (f²)	38589
Structural category	Panelised timber-concrete (podium-core)
Podium	Ground Floor
Core	Concrete
Floor slabs	CLT-concrete
Program	Residential
External Cladding	Wood
Indoor elements exposed	Ceiling
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Competition
Influence	Public/Private
Motivations	Sustainability
Architect	einszueins architektur, AT
Engineer	Woschitz Group, AT
Timber Engineer	Woschitz Group, AT
General Contractor	Strobl Bau-Holzbau, AT
Timber Contractor	Strobl Bau-Holzbau, AT
Timber Supplier:	
Structural Elements	Stora Enso, FI, SE
Floor Elements	Stora Enso, FI, SE
Client	At home Immobilien, AT

SOURCE OF IMAGES

einszueins architektur, Strobl Bau-Holzbau

Gleis 21

Year Completation	2019
Country	Austria
City	Vienna
Number of Storeys	6
Number Timber Storeys	5

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	3992
Total surface built (f²)	42970
Structural category	Panelised timber-concrete (podium-core)
Podium	Ground Floor
Core	Concrete
Floor slabs	CLT-concrete
Program	Residential - Co-housing
External Cladding	Wood
Indoor elements exposed	All the surfaces
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Competition
Influence	Private
Motivations	Sustainability
Architect	einszueins architektur, AT
Engineer	GG Ingeniueure, AT
Timber Engineer	GG Ingeniueure, AT
General Contractor	Schwarzatal, AT
Timber Contractor	Weissenseer Holz-System-Bau, AT
Timber Supplier:	
Structural Elements	Mayr-Melnhof Holz, AT
Floor Elements	XlamConcrete, AT
Client	Baugruppe Gleis 21, AT

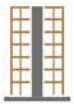
SOURCE OF IMAGES

einszueins architektur, Weissenseer Holz-System-Bau

Hoho Wien

Year Completation	2019
Country	Austria
City	Vienna
Number of Storeys	24
Number Timber Storeys	24

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	25000
Total surface built (f²)	269100
Structural category	 Post-and-Beam timber-concrete (core)
Podium	None
Core	Concrete
Floor slabs	CLT-concrete
Program	Mixed Use (residential-other)
External Cladding	Cement based
Indoor elements exposed	All the surfaces
Building volume	Varying heights

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Sustainability
Architect	Rudiger Leiner Architekten, AT
Engineer	Woschitz Group, AT
Timber Engineer	Woschitz Group, AT
General Contractor	Handler, AT
Timber Contractor	Handler, AT
Timber Supplier:	
Structural Elements	Hasslacher Nordica Timber, AT
Floor Elements	XlamConcrete, AT
Client	Cetus Baudevelopment, AT

SOURCE OF IMAGES

Thomas Lerch, Handler

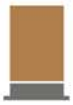
A.2 Benelux

Project (name)	(image)	Storeys (number)	Timber Storeys (number)	Strucutral system (logo)	(category)	Core (material)	Floor Slabs (material)	Total Built Surface (m2)	Program (type)	Facade cladding (material)	Structural timber exposure (category)
Malmo Hus		5	4		Panelised timber-concrete (podium)	CLT	LVL	5400	Residential	Wood	None
Les Closières		5	5		Panelised all-timber	CLT	CLT	800	Residential	Wood	All the surfaces
Patch 22		7	6		Post-and-Beam timber-concrete (podium-core)	Concrete	Glulam-concrete	5400	Residential	Wood	All the surfaces
Kietude		6	6		Panelised timber-concrete-steel (core-steel beams)	Concrete	CLT	720	Residential	Plaster	Walls
Hotel Jakarta		9	8		3D Modular timber-concrete (podium-core)	Concrete	CLT-concrete	16500	Hotel	Curtain wall	All the surfaces

Malmö Hus

Year Completation	2008
Country	The Netherlands
City	Almere
Number of Storeys	5
Number Timber Storeys	4

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	5400
Total surface built (f²)	58126
Structural category	 Panelised timber-concrete (podium)
Podium	Ground Floor
Core	CLT
Floor slabs	LVL
Program	Residential
External Cladding	Wood
Indoor elements exposed	None
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Sustainability
Architect	Tigchelaar architects, NL
Engineer	Lochem - Lüning Adviesburo, NL
Timber Engineer	Ingenieursburo Bartels, NL
General Contractor	Bouwbedrijf Kingma Bouw, NL
Timber Contractor	n/a
Timber Supplier:	
Structural Elements	Züblin Timber, DE
Floor Elements	Metsa Wood , FI
Client	de Alliantie Ontwikkeling, NL

SOURCE OF IMAGES

luning.nl

Les Closières

Year Completation	2015
Country	Belgium
City	Charleroi
Number of Storeys	5
Number Timber Storeys	5

DESIGN DATA

Number of Buildings	2
Total surface built (m²)	800
Total surface built (f²)	8611
Structural category	Panelised all-timber
Podium	None
Core	CLT
Floor slabs	CLT
Program	Residential
External Cladding	Wood
Indoor elements exposed	All the surfaces
Building volume	Varying heights

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Sustainability
Architect	Banneton-Garrino Architects, BE
Engineer	Ney & Partners, BE
Timber Engineer	Ney & Partners, BE
General Contractor	La Sambrienne, BE
Timber Contractor	Laminated Timber Solutions, BE
Timber Supplier:	
Structural Elements	Laminated Timber Solutions, BE
Floor Elements	Laminated Timber Solutions, BE
Client	Le Val d'Heure, BE

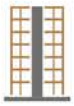
SOURCE OF IMAGES

Ney & Partners

Patch 22

Year Completation	2016
Country	The Netherlands
City	Amsterdam
Number of Storeys	7
Number Timber Storeys	6

DESIGN DATA

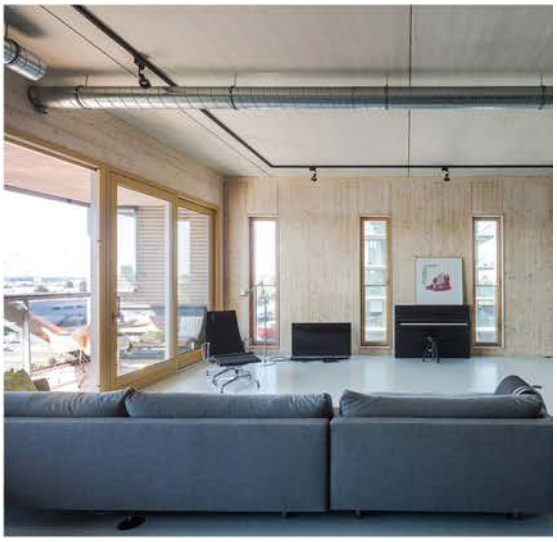
Number of Buildings	1
Total surface built (m²)	5400
Total surface built (f²)	58126
Structural category	 Post-and-Beam timber-concrete (podium-core)
Podium	Ground Floor
Core	Concrete
Floor slabs	Glulam-concrete
Program	Residential
External Cladding	Wood
Indoor elements exposed	All the surfaces
Building volume	Irregular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Technical aspects
Architect	Frantzen et al architecten, NL
Engineer	Pieters Bouwtechniek, NL
Timber Engineer	n/a
General Contractor	Hillen & Roosen, NL
Timber Contractor	Korlam Nederland, NL
Timber Supplier:	
Structural Elements	Mayr-Melnhof Holz, AT
Floor Elements	Laminated Timber Solutions, BE
Client	Lemniskade, NL

SOURCE OF IMAGES

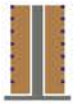
Frantzen et al architecten



Ki-Etude

Year Completation	2018
Country	Belgium
City	Namur
Number of Storeys	6
Number Timber Storeys	6

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	720
Total surface built (f²)	7750
Structural category	 Panelised timber-concrete-steel (core-steel beams)
Podium	None
Core	Concrete
Floor slabs	CLT
Program	Residential
External Cladding	Plaster
Indoor elements exposed	Walls
Building volume	Irregular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Technical aspects
Architect	Specimen Architects, BE
Engineer	Ney & Partners - WOW, BE
Timber Engineer	Ney & Partners - WOW, BE
General Contractor	Invest Immo Belgium, BE
Timber Contractor	Laminated Timber Solutions, BE
Timber Supplier:	
Structural Elements	Laminated Timber Solutions, BE
Floor Elements	Laminated Timber Solutions, BE
Client	Invest Immo Belgium, BE

SOURCE OF IMAGES

Valentin Bianchi, Specimen Architects

Hotel Jakarta

Year Completation	2018
Country	The Netherlands
City	Amsterdam
Number of Storeys	9
Number Timber Storeys	8

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	16500
Total surface built (f²)	177606
Structural category	3D Modular timber-concrete (podium-core)
Podium	Ground Floor
Core	Concrete
Floor slabs	CLT-concrete
Program	Hotel
External Cladding	Curtain wall
Indoor elements exposed	All the surfaces
Building volume	Regular

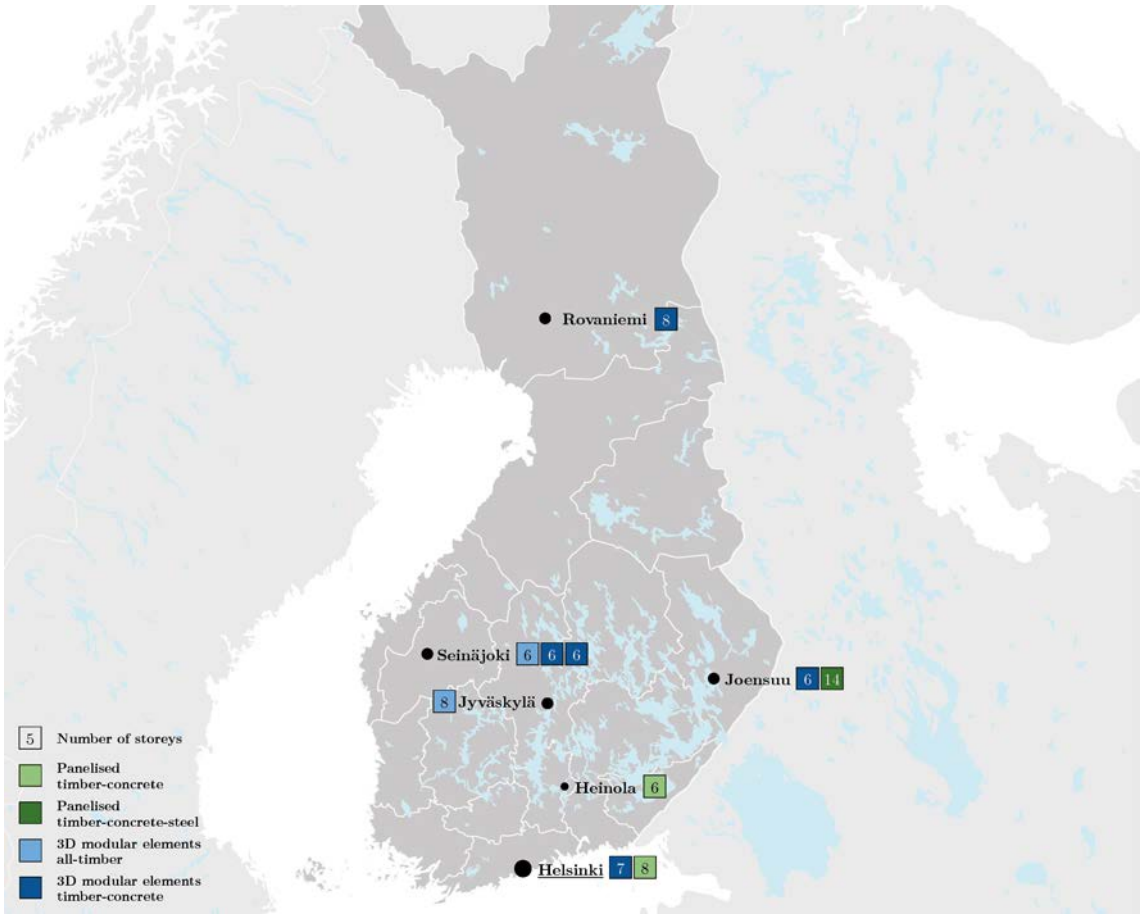
CONTEXTUAL DATA

Type of Commission	Competition
Influence	Public/Private
Motivations	Sustainability
Architect	SeArch, NL
Engineer	Pieters Bouwtechniek, NL
Timber Engineer	Holzleimbau Derix, DE
General Contractor	Bouwbedrijf M. J. de Nijs & Zonen Warmenhuizen, NL
Timber Contractor	Ursem modulaire bouwsystemen, NL
Timber Supplier:	
Structural Elements	Holzleimbau Derix, DE
Floor Elements	Holzleimbau Derix, DE
Client	WestCord Hotels, NL

SOURCE OF IMAGES

alumet.nl, Jhon L. Marshall

A.3 Finland



Project (name)	(image)	Storeys (number)	Timber Storeys (number)	Structutral system (logo)	(category)	Core (material)	Floor Slabs (material)	Total Built Surface (m2)	Program (type)	Facade cladding (material)	Structural timber exposure (category)
Puumera		5	5		Panelised timber-concrete (core)	Concrete	Glulam-concrete	1915	Residential	Wood	Ceiling
Lintuviita		6	5		3D Modular timber-concrete (podium)	CLT	CLT	3100	Residential	Wood	None
Eskolantie		7	6		3D Modular timber-concrete (podium)	CLT	CLT	9876	Residential	Wood	None
Puukuokka		8	8		3D Modular element all-timber	CLT	CLT	8950	Residential	Wood	Ceiling
Mäihä		6	6		3D Modular element all-timber	CLT	CLT	2348	Residential	Wood	Ceiling
Pihapetäjä		6	5		3D Modular timber-concrete (podium)	CLT	CLT	2969	Residential	Wood	Ceiling
Lighthouse Joensuu		14	13		Panelised timber-concrete-steel (podium-steel rods)	LVL	CLT	4800	Student Housing	Other	None
Wood City		8	7		Panelised timber-concrete (podium)	LVL	LVL	8200	Residential	Wood	None
DAS Kelo		8	7		3D Modular timber-concrete (podium)	CLT	CLT	4583	Student Housing	Wood	Ceiling
Seinäjoen Tuohi		6	5		3D Modular timber-concrete (podium)	CLT	CLT	2541	Residential	Wood	Ceiling

Puumera

Year Completation	2012
Country	Finland
City	Heinola
Number of Storeys	5
Number Timber Storeys	5

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	1915
Total surface built (f²)	20613
Structural category	Panelised timber-concrete (core)
Podium	None
Core	Concrete
Floor slabs	Glulam-concrete
Program	Residential
External Cladding	Wood
Indoor elements exposed	Ceiling
Building volume	Pitched roof

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Public/Private
Motivations	Technical aspects
Architect	Vuorelma Arkkitehdit Oy, FI
Engineer	Finnmap Consulting Oy - Insinööritoimisto Puolanne Oy, FI
Timber Engineer	Finnmap Consulting Oy - Insinööritoimisto Puolanne Oy, FI
General Contractor	Rakennusliike Reponen Oy, FI
Timber Contractor	Versowood Oy - Koskisen Oy, FI
Timber Supplier:	
Structural Elements	Versowood Oy - Koskisen Oy, FI
Floor Elements	Versowood Oy - Koskisen Oy, FI
Client	City of Heinola, FI

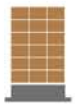
SOURCE OF IMAGES

projektiuutiset.fi, Rakennusliike Reponen Oy

Lintuviita

Year Completation	2013
Country	Finland
City	Seinäjoki
Number of Storeys	6
Number Timber Storeys	5

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	3100
Total surface built (f²)	33368
Structural category	 3D Modular timber-concrete (podium)
Podium	Ground Floor
Core	CLT
Floor slabs	CLT
Program	Residential
External Cladding	Wood
Indoor elements exposed	None
Building volume	Pitched roof

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Public/Private
Motivations	Technical aspects
Architect	Arkkitehtitoimisto Matti, FI
Engineer	Pertti Ruuskanen Engineering, FI
Timber Engineer	Stora Enso, FI, SE
General Contractor	Rakennus K. Karhu Oy, FI
Timber Contractor	Rakennus K. Karhu Oy, FI
Timber Supplier:	
Structural Elements	Stora Enso, FI, SE
Floor Elements	Stora Enso, FI, SE
Client	Lakea Oy, FI

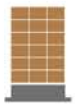
SOURCE OF IMAGES

Stora Enso, Lakea, Tikkurila

Eskolantie

Year Completation	2015
Country	Finland
City	Helsinki
Number of Storeys	7
Number Timber Storeys	6

DESIGN DATA

Number of Buildings	3
Total surface built (m²)	9876
Total surface built (f²)	106305
Structural category	 3D Modular timber-concrete (podium)
Podium	Ground Floor
Core	CLT
Floor slabs	CLT
Program	Residential
External Cladding	Wood
Indoor elements exposed	None
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Competition
Influence	Public
Motivations	Sustainability
Architect	Matti Iiramo Architects, FI
Engineer	Sweco, INT
Timber Engineer	Sweco, INT
General Contractor	SRV Group - Stora Enso, FI
Timber Contractor	n/a
Timber Supplier:	
Structural Elements	Stora Enso, FI, SE
Floor Elements	Stora Enso, FI, SE
Client	Helsinki City Housing Agency ATT, FI

SOURCE OF IMAGES

Tuomas Uuscheimo, blok.ai, Stora Enso

Puukuokka

Year Completation	2015
Country	Finland
City	Jyväskylä
Number of Storeys	8
Number Timber Storeys	8

DESIGN DATA

Number of Buildings	3
Total surface built (m²)	8950
Total surface built (f²)	96338
Structural category	3D Modular element all-timber
Podium	None
Core	CLT
Floor slabs	CLT
Program	Residential
External Cladding	Wood
Indoor elements exposed	Ceiling
Building volume	Pitched roof

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Public/Private
Motivations	Sustainability
Architect	OOPEAA Office, FI
Engineer	Pertti Ruuskanen Engineering, FI
Timber Engineer	SWECO, INT - A-Insinöörit Oy, FI
General Contractor	Keski-suomen Rakennuslinja, FI
Timber Contractor	n/a
Timber Supplier:	
Structural Elements	Stora Enso, FI, SE
Floor Elements	Stora Enso, FI, SE
Client	Lakea Oy, FI

SOURCE OF IMAGES

Mikko Auerniitty, OOPEAA

Mäihä

Year Completation	2016
Country	Finland
City	Seinäjoki
Number of Storeys	6
Number Timber Storeys	6

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	2348
Total surface built (f²)	25274
Structural category	3D Modular element all-timber
Podium	None
Core	CLT
Floor slabs	CLT
Program	Residential
External Cladding	Wood
Indoor elements exposed	Ceiling
Building volume	Pitched roof

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Public/Private
Motivations	Sustainability
Architect	A-Live, FI
Engineer	Sweco, INT
Timber Engineer	Insinööritoimisto Seinäjoen Rakennustekniikka Oy, FI
General Contractor	Insinööritoimisto Seinäjoen Rakennustekniikka Oy, FI
Timber Contractor	n/a
Timber Supplier:	
Structural Elements	Stora Enso, FI, SE
Floor Elements	Stora Enso, FI, SE
Client	Lakea Oy, FI

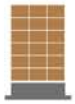
SOURCE OF IMAGES

pefc.org, Sisustussuunnittelu Mäkelä & Roos, Stora Enso

Pihapetäjä

Year Completation	2017
Country	Finland
City	Joensuu
Number of Storeys	6
Number Timber Storeys	5

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	2969
Total surface built (f²)	31958
Structural category	 3D Modular timber-concrete (podium)
Podium	Ground Floor
Core	CLT
Floor slabs	CLT
Program	Residential
External Cladding	Wood
Indoor elements exposed	Ceiling
Building volume	Pitched roof

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Public/Private
Motivations	Sustainability
Architect	OOPEAA Office, FI
Engineer	Insinööritoimisto Joensuun Juva Oy - Petteri Peltomaa, FI
Timber Engineer	Insinööritoimisto Joensuun Juva Oy - Petteri Peltomaa, FI
General Contractor	Rakennustoimisto Eero Reijonen Oy, FI
Timber Contractor	Rakennustoimisto Eero Reijonen Oy, FI
Timber Supplier:	
Structural Elements and Floor Elements	Pyhännän Rakennustuote Oy, FI
Client	Foundation for the Promotion of Karelian Culture, FI

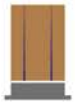
SOURCE OF IMAGES

Joensuun Pihapetäjä, woodarchitecture

Lighthouse Joensuu

Year Completation	2018
Country	Finland
City	Joensuu
Number of Storeys	14
Number Timber Storeys	13

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	4800
Total surface built (f²)	51667
Structural category	 Panelised timber-concrete-steel (podium-steel rods)
Podium	Ground Floor
Core	LVL
Floor slabs	CLT
Program	Student Housing
External Cladding	Other
Indoor elements exposed	None
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Public
Motivations	Sustainability
Architect	Arcadia Oy Arkkitehtitoimisto, FI
Engineer	A-Insinöörit Oy, FI
Timber Engineer	A-Insinöörit Oy, FI
General Contractor	Rakennustoimisto Eero Reijonen Oy, FI
Timber Contractor	Rakennustoimisto Eero Reijonen Oy, FI
Timber Supplier:	
Structural Elements	Stora Enso, FI, SE
Floor Elements	Stora Enso, FI, SE
Client	Student Housing Oy Joensuun Elli, FI

SOURCE OF IMAGES

wooddesignandbuilding.com, Maaseudun Tulevaisuus, Lari Lievonen, Stora Enso

Wood City Residential Buildings

Year Completation	2018
Country	Finland
City	Helsinki
Number of Storeys	8
Number Timber Storeys	7

DESIGN DATA

Number of Buildings	2
Total surface built (m²)	8200
Total surface built (f²)	88265
Structural category	Panelised timber-concrete (podium)
Podium	Ground Floor
Core	LVL
Floor slabs	LVL
Program	Residential
External Cladding	Wood
Indoor elements exposed	None
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Competition
Influence	Public
Motivations	Sustainability
Architect	Anttinen Oiva Arkkitehdit Oy, FI
Engineer	Sweco, INT
Timber Engineer	Woodcon, NO, SE, AT
General Contractor	SRV Group - Stora Enso, FI
Timber Contractor	Woodcon, NO, SE, AT
Timber Supplier:	
Structural Elements	Stora Enso, FI, SE
Floor Elements	Stora Enso, FI, SE
Client	Helsinki Housing Production, FI

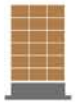
SOURCE OF IMAGES

accoya.com, SRVGroup, Stora Enso

DAS Kelo

Year Completation	2019
Country	Finland
City	Rovaniemi
Number of Storeys	8
Number Timber Storeys	7

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	4583
Total surface built (f²)	49331
Structural category	 3D Modular timber-concrete (podium)
Podium	Ground Floor
Core	CLT
Floor slabs	CLT
Program	Student Housing
External Cladding	Wood
Indoor elements exposed	Ceiling
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Competition
Influence	Public
Motivations	Sustainability
Architect	Artto Palo Rossi Tikka Oy, FI
Engineer	A-Insinöörit Oy, FI
Timber Engineer	A-Insinöörit Oy, FI
General Contractor	Lapin mestarirakentajat Oy, FI
Timber Contractor	Space Elementti-Sampo Oy, FI
Timber Supplier:	
Structural Elements	Space Elementti-Sampo Oy, FI
Floor Elements	Space Elementti-Sampo Oy, FI
Client	Domus Arctica Foundation - University of Lappland, FI

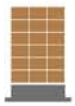
SOURCE OF IMAGES

Artto Palo Rossi Tikka Architects, Elementti Sampo

Seinäjoen Tuohi

Year Completation	2019
Country	Finland
City	Seinäjoki
Number of Storeys	6
Number Timber Storeys	5

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	2541
Total surface built (f²)	27351
Structural category	 3D Modular timber-concrete (podium)
Podium	Ground Floor
Core	CLT
Floor slabs	CLT
Program	Residential
External Cladding	Wood
Indoor elements exposed	Ceiling
Building volume	Pitched roof

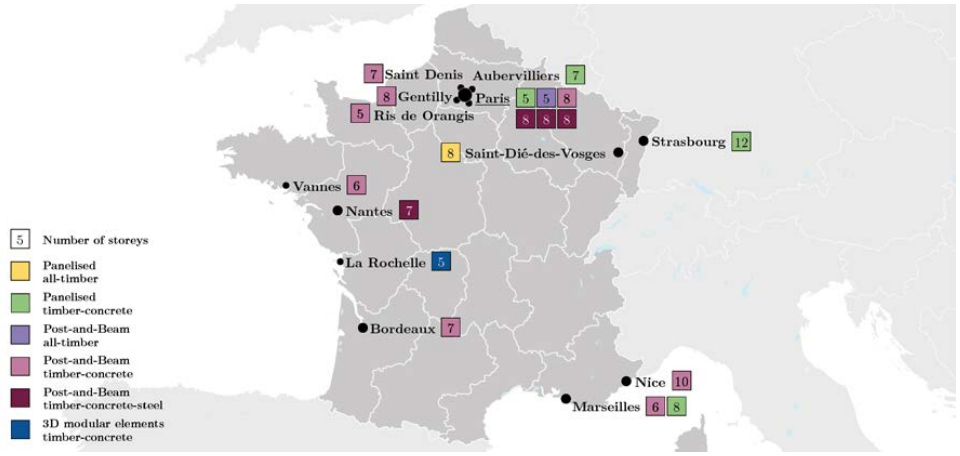
CONTEXTUAL DATA

Type of Commission	Direct
Influence	Public/Private
Motivations	Sustainability
Architect	Casagrande Laboratory Center of Urban Research , FI
Engineer	A-Insinöörit Oy, FI
Timber Engineer	A-Insinöörit Oy, FI
General Contractor	n/a
Timber Contractor	Space Elementti-Sampo Oy, FI
Timber Supplier:	
Structural Elements	Space Elementti-Sampo Oy, FI
Floor Elements	Space Elementti-Sampo Oy, FI
Client	Lakea Oy, FI

SOURCE OF IMAGES

Casagrande Laboratory, Lakea

A.4 France

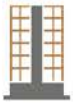


Project (name)	(image)	Storeys (number)	Timber Storeys (number)	Structural system (logo)	(category)	Core (material)	Floor Slabs (material)	Total Built Surface (m2)	Program (type)	Facade cladding (material)	Structural timber exposure (category)
Maison de l'Inde		8	7		Post-and-Beam timber-concrete (podium-core)	Concrete	Glulam	2860	Student Housing	Wood	None
Crous Jean Jouzel		5	4		3D Modular timber-concrete (podium)	CLT	CLT	3700	Student Housing	Metal	Ceiling
Residences J.Ferry		8	8		Panelised all-timber and frame	CLT	CLT	2702	Residential	Other	All the surfaces
Ywood Les Docks Libres		6	5		Post-and-Beam timber-concrete (podium-core)	Concrete	CLT	3637	Office	Wood	All the surfaces
Bâtiment Max Weber		5	5		Post-and-Beam all-timber	CLT	Glulam-concrete	4904	Education	Metal	All the surfaces
DDTM		6	5		Post-and-Beam timber-concrete (podium-core)	Concrete	Glulam-concrete	6779	Office	Wood/ Metal	Columns and beams
Quai de la Borde		5	4		Post-and-Beam timber-concrete (podium-core)	Concrete	CLT	8800	Residential	Plaster	None
Rue des Ardennes		5	4		Panelised timber-concrete (podium)	CLT	CLT	1000	Residential	Wood	None
Lucien Cornil Student Residence		8	8		Panelised timber-concrete (core)	Concrete	CLT	4352	Student Housing	Wood/ Metal	All the surfaces
Opalia		8	8		Post-and-Beam timber-concrete-steel (core-steel beams)	Concrete	CLT	6500	Office	Wood	All the surfaces
Green Office® Enjoy		8	5		Post-and-Beam timber-concrete-steel (podium-core-steel bracing)	Concrete	CLT	17400	Office	Metal	Columns and beams
Kibori		7	6		Post-and-Beam timber-concrete-steel (podium-core-steel bracing)	Concrete	CLT	4620	Office	Metal	All the surfaces
Perspective		7	6		Post-and-Beam timber-concrete (podium-core)	Concrete	LVL-concrete	5156	Office	Wood/ Metal	Columns and beams
Jo&Joe		8	7		Post-and-Beam timber-concrete (podium-core)	Concrete	CLT	7000	Hotel	Metal	All the surfaces
Palazzo Nice Meridia		10	9		Post-and-Beam timber-concrete (podium-core)	Concrete	CLT	7885	Office	Metal	All the surfaces
Pont de Flandres Batiment 007		8	7		Post-and-Beam timber-concrete-steel (podium-core-steel beams)	Concrete	Glulam-concrete	8577	Office	Curtain wall	Columns and beams
Pop-Up		7	6		Panelised timber-concrete (podium-core)	Concrete	CLT	1900	Residential - Co-housing	Other	None
Pulse		7	6		Post-and-Beam timber-concrete (podium-core)	Concrete	CLT-glulam	28450	Office	Wood/ Metal	All the surfaces
Sensations		12	11		Panelised timber-concrete (podium and frame)	CLT	CLT	9146	Residential	Wood/ Metal	None

Maison de l'Inde

Year Completation	2013
Country	France
City	Paris
Number of Storeys	8
Number Timber Storeys	7

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	2860
Total surface built (f²)	30785
Structural category	 Post-and-Beam timber-concrete (podium-core)
Podium	Ground Floor
Core	Concrete
Floor slabs	Glulam
Program	Student Housing
External Cladding	Wood
Indoor elements exposed	None
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Building erection speed
Architect	Libsky Rollet Architects, FR
Engineer	C&E ingénierie des structures, FR
Timber Engineer	C&E ingénierie des structures, FR
General Contractor	EGMB, FR
Timber Contractor	Rubner, IT
Timber Supplier:	
Structural Elements	Rubner, IT
Floor Elements	Rubner, IT
Client	Maison de L'Inde - Indian Government, FR

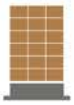
SOURCE OF IMAGES

Rubner, Travaux:Habiter

Crous Jean Jouzel

Year Completation	2014
Country	France
City	La Rochelle
Number of Storeys	5
Number Timber Storeys	4

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	3700
Total surface built (f²)	39827
Structural category	 3D Modular timber-concrete (podium)
Podium	Ground Floor
Core	CLT
Floor slabs	CLT
Program	Student Housing
External Cladding	Metal
Indoor elements exposed	Ceiling
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Public
Motivations	Building erection speed
Architect	Sourd-Durand Architectes, FR
Engineer	Lapasserie Ingénierie, FR
Timber Engineer	Ingénierie Bois, FR
General Contractor	Eiffage Construction, FR
Timber Contractor	Lignatec KLH, FR
Timber Supplier:	
Structural Elements	KLH, AT
Floor Elements	KLH, AT
Client	Crous (Poitiers), FR

SOURCE OF IMAGES

Crous, Lignatec KLH

Residences J.Ferry

Year Completation	2014
Country	France
City	St.Diè des Vosges
Number of Storeys	8
Number Timber Storeys	8

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	2702
Total surface built (f²)	29084
Structural category	Panelised all-timber and frame
Podium	None
Core	CLT
Floor slabs	CLT
Program	Residential
External Cladding	Other
Indoor elements exposed	All the surfaces
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Sustainability
Architect	ASP architecture, FR
Engineer	Ingénierie Bois, FR
Timber Engineer	Ingénierie Bois, FR
General Contractor	Sertelet Yves, FR
Timber Contractor	Lignatec KLH, FR
Timber Supplier:	
Structural Elements	KLH, AT
Floor Elements	KLH, AT
Client	Le Toit Vosgien, FR

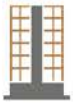
SOURCE OF IMAGES

Lignatec KLH, ESBG 2015

Ywood Les Docks Libres

Year Completation	2015
Country	France
City	Marseilles
Number of Storeys	6
Number Timber Storeys	5

DESIGN DATA

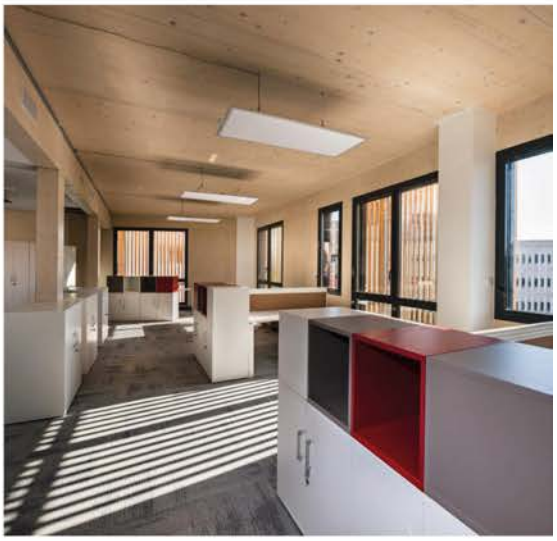
Number of Buildings	1
Total surface built (m²)	3637
Total surface built (f²)	39149
Structural category	 Post-and-Beam timber-concrete (podium-core)
Podium	Ground Floor
Core	Concrete
Floor slabs	CLT
Program	Office
External Cladding	Wood
Indoor elements exposed	All the surfaces
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Sustainability
Architect	Carta Associés, FR
Engineer	n/a
Timber Engineer	Mathis, FR
General Contractor	Nexity, FR
Timber Contractor	Binderholz, AT
Timber Supplier:	
Structural Elements	Binderholz, AT
Floor Elements	Binderholz, AT
Client	Fonciere Inea, FR

SOURCE OF IMAGES

Turisme-marseille, Mathis



Bâtiment Max Weber

Year Completation	2016
Country	France
City	Paris
Number of Storeys	5
Number Timber Storeys	5

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	4904
Total surface built (f²)	52787
Structural category	Post-and-Beam all-timber
Podium	None
Core	CLT
Floor slabs	Glulam-concrete
Program	Education
External Cladding	Metal
Indoor elements exposed	All the surfaces
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Competition
Influence	Public
Motivations	Sustainability
Architect	Atelier Pascal Gontier, FR
Engineer	SLH engineering, FR
Timber Engineer	KLH, AT
General Contractor	Icade Promotion, FR
Timber Contractor	Lignatec KLH, FR
Timber Supplier:	
Structural Elements	KLH, AT
Floor Elements	KLH, AT
Client	Université Paris Ouest Nanterre La Défense, FR

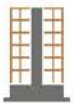
SOURCE OF IMAGES

Atelier Pascal Gontier, Lignatec KLH

DDTM

Year Completation	2016
Country	France
City	Vannes
Number of Storeys	6
Number Timber Storeys	5

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	6779
Total surface built (f²)	72969
Structural category	 Post-and-Beam timber-concrete (podium-core)
Podium	Ground Floor
Core	Concrete
Floor slabs	Glulam-concrete
Program	Office
External Cladding	Wood/Metal
Indoor elements exposed	Columns and beams
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Competition
Influence	Public
Motivations	Sustainability
Architect	AIA Associés, FR
Engineer	AIA Associés, FR
Timber Engineer	AIA Associés, FR
General Contractor	n/a
Timber Contractor	Cruard Charpente, FR
Timber Supplier:	
Structural Elements	Cruard Charpente, FR
Floor Elements	Cruard Charpente, FR
Client	Préfecture du Morbihan, FR

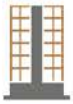
SOURCE OF IMAGES

Frédéric Baron, Cruard Charpente

Quai de la Borde

Year Completation	2016
Country	France
City	Ris de Orangis
Number of Storeys	5
Number Timber Storeys	4

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	8800
Total surface built (f²)	94723
Structural category	 Post-and-Beam timber-concrete (podium-core)
Podium	Ground Floor
Core	Concrete
Floor slabs	CLT
Program	Residential
External Cladding	Plaster
Indoor elements exposed	None
Building volume	Pitched roof

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Sustainability
Architect	Wilmotte & Associés Architectes, FR
Engineer	S2T, FR
Timber Engineer	Sylva Conseil, FR
General Contractor	Eiffage Construction, FR
Timber Contractor	Woodeum, FR
Timber Supplier:	
Structural Elements	Mathis, FR
Floor Elements	Stora Enso, FI SE
Client	Woodeum, FR

SOURCE OF IMAGES

Thibaut Voisin, Mathis

Rue des Ardennes

Year Completation	2016
Country	France
City	Paris
Number of Storeys	5
Number Timber Storeys	4

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	1000
Total surface built (f²)	10764
Structural category	Panelised timber-concrete (podium)
Podium	Ground Floor
Core	CLT
Floor slabs	CLT
Program	Residential
External Cladding	Wood
Indoor elements exposed	None
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Technical aspects
Architect	Atelier Audebau - Fokkena, FR
Engineer	Brezillon, FR
Timber Engineer	Les Charpentiers de l'Atlantique, FR
General Contractor	Brezillon, FR
Timber Contractor	Les Charpentiers de l'Atlantique, - Woodeum, FR
Timber Supplier:	
Structural Elements	Stora Enso, FI, SE
Floor Elements	Stora Enso, FI, SE
Client	OGIF, FR

SOURCE OF IMAGES

Achdou, BBCA

Lucien Cornil Student Residence

Year Completation	2017
Country	France
City	Marseilles
Number of Storeys	8
Number Timber Storeys	8

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	4352
Total surface built (f²)	46845
Structural category	Panelised timber-concrete (core)
Podium	None
Core	Concrete
Floor slabs	CLT
Program	Student Housing
External Cladding	Wood/Metal
Indoor elements exposed	All the surfaces
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Competition
Influence	Public
Motivations	Building erection speed
Architect	A-Architecture, FR
Engineer	n/a
Timber Engineer	Arbonis, FR
General Contractor	Travaux du Midi (Vinci), FR
Timber Contractor	Arbonis, FR
Timber Supplier:	
Structural Elements	Arbonis, FR
Floor Elements	Arbonis, FR
Client	Crous (Aix-Marseille Avignon), FR

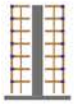
SOURCE OF IMAGES

Benoit Wehrlé

Opalia

Year Completation	2017
Country	France
City	Paris
Number of Storeys	8
Number Timber Storeys	8

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	6500
Total surface built (f²)	69966
Structural category	 Post-and-Beam timber-concrete-steel (core-steel beams)
Podium	None
Core	Concrete
Floor slabs	CLT
Program	Office
External Cladding	Wood
Indoor elements exposed	All the surfaces
Building volume	Varying heights

CONTEXTUAL DATA

Type of Commission	Competition
Influence	Public
Motivations	Sustainability
Architect	ArtBuild Architect, FR
Engineer	SNC Lavalin (now Edeis), FR
Timber Engineer	SNC Lavalin (now Edeis) - Briand, FR
General Contractor	SNC Lavalin - Arcora - Quadrus - Briand, FR
Timber Contractor	Briand - Lignatec KLH, FR
Timber Supplier:	
Structural Elements	KLH, AT
Floor Elements	KLH, AT
Client	SEMAPA, Buelens Real Estate, FR

SOURCE OF IMAGES

Paul Kozlowski, Art & Build

Green Office® Enjoy

Year Completation	2018
Country	France
City	Paris
Number of Storeys	8
Number Timber Storeys	5

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	17400
Total surface built (f²)	187294
Structural category	Post-and-Beam timber-concrete-steel (podium-core-steel bracing)
Podium	Up to second floor
Core	Concrete
Floor slabs	CLT
Program	Office
External Cladding	Metal
Indoor elements exposed	Columns and beams
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Technical aspects
Architect	Baumschlager Eberle, INT
Engineer	AIA Associés, FR
Timber Engineer	AIA Associés, FR
General Contractor	n/a
Timber Contractor	Mathis, FR
Timber Supplier:	
Structural Elements	Mathis, FR
Floor Elements	Mathis, FR
Client	Bouygues Immobilier - Icade, FR

SOURCE OF IMAGES

Observatoire BBC

Kibori

Year Completation	2018
Country	France
City	Nantes
Number of Storeys	7
Number Timber Storeys	6

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	4620
Total surface built (f²)	49730
Structural category	Post-and-Beam timber-concrete-steel (podium-core-steel bracing)
Podium	Ground Floor
Core	Concrete
Floor slabs	CLT
Program	Office
External Cladding	Metal
Indoor elements exposed	All the surfaces
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	n/a
Influence	n/a
Motivations	Sustainability
Architect	ArtBuild Architect, FR
Engineer	Novam Ingénierie, FR
Timber Engineer	ECTS, FR
General Contractor	ADI , FR
Timber Contractor	Cruard Charpente, FR
Timber Supplier:	
Structural Elements	Cruard Charpente, FR
Floor Elements	Cruard Charpente, FR
Client	Sogeprom - BNP Paribas Real, FR

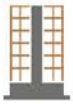
SOURCE OF IMAGES

cruard-charpente.com, nantes-amenagement.fr

Perspective - ZAC Euratlantique

Year Completation	2018
Country	France
City	Bordeaux
Number of Storeys	7
Number Timber Storeys	6

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	5156
Total surface built (f²)	55499
Structural category	 Post-and-Beam timber-concrete (podium-core)
Podium	Ground Floor
Core	Concrete
Floor slabs	LVL-Concrete
Program	Office
External Cladding	Wood/Metal
Indoor elements exposed	Columns and beams
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Public/Private
Motivations	Sustainability
Architect	Lainsé Roussel, FR
Engineer	Terrell - Pouget Consultants - Ecotech - Emacoustic, FR
Timber Engineer	Terrell - Pouget Consultants - Ecotech - Emacoustic, FR
General Contractor	Pyrenees carpenters, FR
Timber Contractor	Pyrenees carpenters, FR
Timber Supplier:	
Structural Elements	Piveteau bois, FR
Floor Elements	Stora Enso, FI, SE
Client	Pichet Promotion, FR

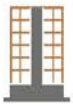
SOURCE OF IMAGES

DREAM, Claire Thibault

Jo & Joe

Year Completation	2019
Country	France
City	Gentilly
Number of Storeys	8
Number Timber Storeys	7

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	7000
Total surface built (f²)	75348
Structural category	 Post-and-Beam timber-concrete (podium-core)
Podium	Ground Floor
Core	Concrete
Floor slabs	CLT
Program	Hotel
External Cladding	Metal
Indoor elements exposed	All the surfaces
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Technical aspects
Architect	Jean-Paul Viguier et Associés, FR
Engineer	Terrell, FR
Timber Engineer	Demathieu Bard, FR
General Contractor	Artelia Bâtiment et Industrie, FR
Timber Contractor	Demathieu Bard, FR
Timber Supplier:	
Structural Elements	Egoin, ES
Floor Elements	Egoin, ES
Client	Accor Hotels, FR

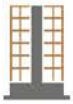
SOURCE OF IMAGES

JO&JOE Paris, Le Bras Frères, Pascal Poggi

Palazzo Nice Meridia

Year Completation	2019
Country	France
City	Nice
Number of Storeys	10
Number Timber Storeys	9

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	7885
Total surface built (f²)	84874
Structural category	 Post-and-Beam timber-concrete (podium-core)
Podium	Ground Floor
Core	Concrete
Floor slabs	CLT
Program	Office
External Cladding	Metal
Indoor elements exposed	All the surfaces
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Sustainability
Architect	Marc Lehmann Architect, FR
Engineer	Egis Concept - BG Ingénieurs, FR
Timber Engineer	CBS, FR
General Contractor	Cecaz - Groupe Nexity, FR
Timber Contractor	Lifteam, FR
Timber Supplier:	
Structural Elements	Lifteam, FR
Floor Elements	Lifteam, FR
Client	Eco-Vallée Plaine du Var, FR

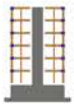
SOURCE OF IMAGES

Antonie Duhamel

Pont de Flandres Batiment 007

Year Completation	2019
Country	France
City	Paris
Number of Storeys	8
Number Timber Storeys	7

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	8577
Total surface built (f²)	92323
Structural category	 Post-and-Beam timber-concrete-steel (podium-core-steel beams)
Podium	Ground Floor
Core	Concrete
Floor slabs	Glulam-concrete
Program	Office
External Cladding	Curtain wall
Indoor elements exposed	Columns and beams
Building volume	Pitched roof

CONTEXTUAL DATA

Type of Commission	Competition
Influence	Private
Motivations	Sustainability
Architect	Anne Carcelen architecte, FR
Engineer	AIA Associés, FR
Timber Engineer	AIA Associés, FR
General Contractor	Spie batignolles - Mathis, FR
Timber Contractor	Mathis, FR
Timber Supplier:	
Structural Elements	Mathis, FR
Floor Elements	Mathis, FR
Client	Icade Promotion, FR

SOURCE OF IMAGES

Tiltandshoot, Nicolas Grosmond, Takuji Shimmura

Pop-Up

Year Completation	2019
Country	France
City	Aubervilliers
Number of Storeys	7
Number Timber Storeys	6

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	1900
Total surface built (f²)	20452
Structural category	Panelised timber-concrete (podium-core)
Podium	Ground Floor
Core	Concrete
Floor slabs	CLT
Program	Residential - Co-housing
External Cladding	Other
Indoor elements exposed	None
Building volume	Varying heights

CONTEXTUAL DATA

Type of Commission	Competition
Influence	Private
Motivations	Sustainability
Architect	Wild Rabbits Architecture, FR
Engineer	AIA Associés, FR
Timber Engineer	ICM - Artofact, FR
General Contractor	Charpente Cénomane, FR
Timber Contractor	Lignatec KLH, FR
Timber Supplier:	
Structural Elements	KLH, AT
Floor Elements	KLH, AT
Client	OPH Aubervilliers, FR

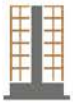
SOURCE OF IMAGES

Wild Rabbits Architecture

Pulse

Year Completation	2019
Country	France
City	Saint Denis
Number of Storeys	7
Number Timber Storeys	6

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	28450
Total surface built (f²)	306236
Structural category	 Post-and-Beam timber-concrete (podium-core)
Podium	Ground Floor
Core	Concrete
Floor slabs	CLT-Glulam
Program	Office
External Cladding	Wood/Metal
Indoor elements exposed	All the surfaces
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Competition
Influence	Private
Motivations	Sustainability
Architect	BFV architectes (Fassio Viaud Architectes), FR
Engineer	Barthès , FR
Timber Engineer	Barthès , FR
General Contractor	Bateg - Vinci Construction France, FR
Timber Contractor	Mathis, FR
Timber Supplier:	
Structural Elements	Mathis, FR
Floor Elements	Mathis, FR
Client	Icade Promotion, FR

SOURCE OF IMAGES

BFV Architectes, Barthès

Sensations

Year Completation	2019
Country	France
City	Strasbourg
Number of Storeys	12
Number Timber Storeys	11

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	9146
Total surface built (f²)	98448
Structural category	Panelised timber-concrete (podium and frame)
Podium	Ground Floor
Core	CLT
Floor slabs	CLT
Program	Residential
External Cladding	Wood/Metal
Indoor elements exposed	None
Building volume	Regular

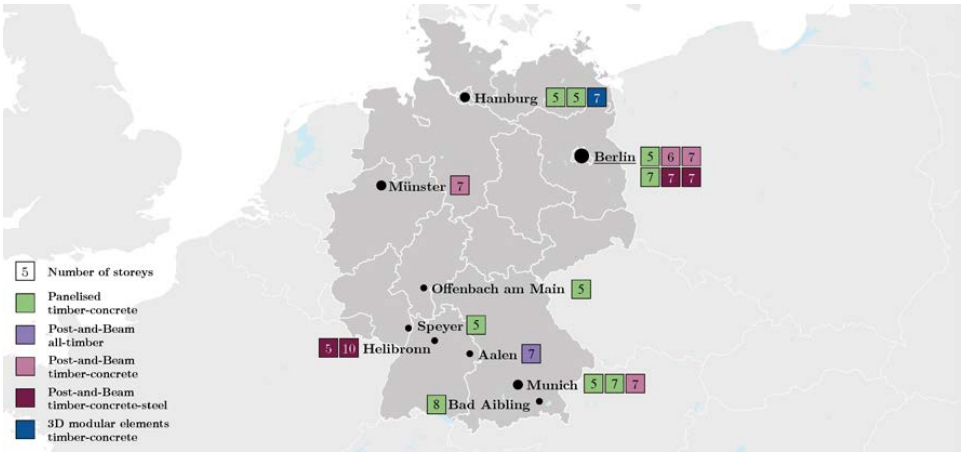
CONTEXTUAL DATA

Type of Commission	Competition
Influence	Private
Motivations	Sustainability
Architect	ASP Architecture - KOZ Architectes, FR
Engineer	Ingénierie Bois, FR
Timber Engineer	Ingénierie Bois, FR
General Contractor	Eiffage Construction, FR
Timber Contractor	Lignatec KLH, FR
Timber Supplier:	
Structural Elements	KLH, AT
Floor Elements	KLH, AT
Client	Bouygues Immobilier, FR

SOURCE OF IMAGES

C. Septet, peterson.fr, batirama

A.5 Germany

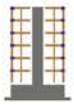


Project (name)	(image)	Storeys (number)	Timber Storeys (number)	Strucutral system (logo)	(category)	Core (material)	Floor Slabs (material)	Total Built Surface (m2)	Program (type)	Facade cladding (material)	Structural timber exposure (category)
E3		7	6		Post-and-Beam timber-concrete-steel (podium-core-steel beams)	Concrete	DLT	4670	Residential - Co-housing	Plaster	Ceiling
Prenzlauer Berg		5	4		Panelised timber-concrete (podium-core)	Concrete	CLT	5720	Residential - Co-housing	Plaster	None
Holz8		8	8		Panelised timber-concrete (core)	Concrete	CLT	1741	Mixed Use (residential-office)	Wood	Ceiling
3XGrün		6	5		Post-and-Beam timber-concrete (podium-core)	Concrete	CLT	2900	Residential - Co-housing	Metal	All the surfaces
Wälderhaus		5	3		Panelised timber-concrete (podium-core)	Concrete	CLT	5910	Hotel	Wood	All the surfaces
WoodCube		5	5		Panelised timber-concrete (core)	Concrete	CLT	1479	Residential	Wood	All the surfaces
C13		7	6		Post-and-Beam timber-concrete-steel (podium-core-steel beams)	Concrete	DLT-concrete	3682	Mixed Use (residential-office)	Plaster	Ceiling
Kampa K8		7	7		Post-and-Beam all-timber	CLT	CLT	3386	Office	Wood	All the surfaces
Nachverdichtung Speyer		5	5		Panelised timber-concrete (core)	Concrete	CLT	1185	Residential	Plaster	None
H7		7	6		Post-and-Beam timber-concrete (podium-core)	Concrete	Glulam-concrete	7000	Office	Metal	All the surfaces
Wohnen Offenbach		5	4		Panelised timber-concrete (podium-core)	Concrete	CLT-concrete	1578	Residential - Social Housing	Wood	None
Woodie		7	6		3D Modular timber-concrete (podium-core)	Concrete	CLT	13510	Student Housing	Wood	All the surfaces
Dantebad		5	4		Panelised timber-concrete (podium)	CLT	CLT	4630	Residential - Social Housing	Wood	Ceiling
Lynarstrasse Berlin		7	6		Post-and-Beam timber-concrete (podium)	CLT	CLT	7350	Residential - Social Housing	Wood	All the surfaces
Famju		5	4		Post-and-Beam timber-concrete-steel (podium-core-steel beams)	Concrete	CLT	1570	Residential	Plaster	None
Skaio		10	9		Post-and-Beam timber-concrete-steel (podium-core-steel beams)	Concrete	CLT	5685	Residential	Metal	All the surfaces
WA14 West		7	6		Post-and-Beam timber-concrete (podium-core)	Concrete	CLT-concrete	9215	Residential - Social Housing	Wood	None
WA15 West		7	6		Panelised timber-concrete (podium-core)	Concrete	CLT	6920	Residential - Social Housing	Wood	None
Walden 48		7	7		Panelised timber-concrete (core)	Concrete	CLT-concrete	7500	Residential - Co-housing	Wood/ Metal	All the surfaces

E3

Year Completation	2007
Country	Germany
City	Berlin
Number of Storeys	7
Number Timber Storeys	6

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	4670
Total surface built (f²)	50268
Structural category	 Post-and-Beam timber-concrete-steel (podium-core-steel beams)
Podium	Ground Floor
Core	Concrete
Floor slabs	DLT
Program	Residential - Co-housing
External Cladding	Plaster
Indoor elements exposed	Ceiling
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Sustainability
Architect	Kaden-Lager Architekten, DE
Engineer	Bois Consult Natterer, CH
Timber Engineer	Bois Consult Natterer, CH - KLH, AT
General Contractor	n/a
Timber Contractor	KLH, AT
Timber Supplier:	
Structural Elements	KLH, AT
Floor Elements	KLH, AT
Client	e3 Baugruppe, DE

SOURCE OF IMAGES

Bernd Borchardt, KLH

Prenzlauer Berg

Year Completation	2010
Country	Germany
City	Berlin
Number of Storeys	5
Number Timber Storeys	4

DESIGN DATA

Number of Buildings	3
Total surface built (m²)	5720
Total surface built (f²)	61570
Structural category	Panelised timber-concrete (podium-core)
Podium	Ground Floor
Core	Concrete
Floor slabs	CLT
Program	Residential - Co-housing
External Cladding	Plaster
Indoor elements exposed	None
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Sustainability
Architect	Müllers Büro, DE
Engineer	Peter Wittig, DE
Timber Engineer	Prof. Dr. Rug. Wittenberge, DE
General Contractor	Kreutner & Schmälzlin, DE
Timber Contractor	ABA Holz van Kempen, DE
Timber Supplier:	
Structural Elements	KLH, AT
Floor Elements	KLH, AT
Client	Baugruppe Zur Börse, DE

SOURCE OF IMAGES

Müllers Büro, ABA Holz

Holz8

Year Completation	2011
Country	Germany
City	Bad Aibling
Number of Storeys	8
Number Timber Storeys	8

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	1741
Total surface built (f²)	18740
Structural category	Panelised timber-concrete (core)
Podium	None
Core	Concrete
Floor slabs	CLT
Program	Mixed Use (residential-office)
External Cladding	Wood
Indoor elements exposed	Ceiling
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Public/Private
Motivations	Technical aspects
Architect	Schankula Architekten, DE
Engineer	bauart Konstruktions, DE
Timber Engineer	Huber & Sohn, DE
General Contractor	Huber & Sohn, DE
Timber Contractor	Huber & Sohn, DE
Timber Supplier:	
Structural Elements	Binderholz, AT
Floor Elements	Binderholz, AT
Client	B\&O Gruppe, DE

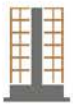
SOURCE OF IMAGES

Dataholz, Schankula-Architekten

3XGrün

Year Completation	2012
Country	Germany
City	Berlin
Number of Storeys	6
Number Timber Storeys	5

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	2900
Total surface built (f²)	31216
Structural category	 Post-and-Beam timber-concrete (podium-core)
Podium	Ground Floor
Core	Concrete
Floor slabs	CLT
Program	Residential - Co-housing
External Cladding	Metal
Indoor elements exposed	Ceiling, Columns and beams
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Public/Private
Motivations	Sustainability
Architect	IfuH – Institut für urbanen Holzbau, et al, DE
Engineer	ifb Frohloff, Staffa, Kühl, Ecker, DE
Timber Engineer	A-Z Holzbau, DE
General Contractor	n/a
Timber Contractor	Züblin Timber, DE - Metsa, FI
Timber Supplier:	
Structural Elements	Züblin Timber, DE - Metsa, FI
Floor Elements	Züblin Timber, DE - Metsa, FI
Client	Baugruppe 3xgrün GbR, DE

SOURCE OF IMAGES

Stefan Müller

Wälderhaus

Year Completation	2012
Country	Germany
City	Hamburg
Number of Storeys	5
Number Timber Storeys	3

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	5910
Total surface built (f²)	63615
Structural category	Panelised timber-concrete (podium-core)
Podium	Up to 1 floor
Core	Concrete
Floor slabs	CLT
Program	Hotel
External Cladding	Wood
Indoor elements exposed	All the surfaces
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	n/a
Influence	Public
Motivations	n/a
Architect	Andreas Heller Architects & Designers, DE
Engineer	Assmann Beraten-Planen, DE
Timber Engineer	Assmann Beraten-Planen, DE
General Contractor	Holzbau Heinrich Haveloh, DE
Timber Contractor	Holzbau Heinrich Haveloh, DE
Timber Supplier:	
Structural Elements	Züblin Timber, DE
Floor Elements	Züblin Timber, DE
Client	Schutzgemeinschaft Deutscher Wald (SDW), DE

SOURCE OF IMAGES

Waelderhouse.de, Kay Riechers

WoodCube

Year Completation	2013
Country	Germany
City	Hamburg
Number of Storeys	5
Number Timber Storeys	5

DESIGN DATA

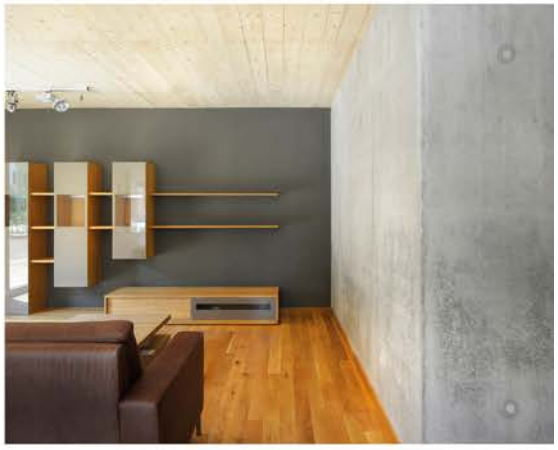
Number of Buildings	1
Total surface built (m²)	1479
Total surface built (f²)	15920
Structural category	Panelised timber-concrete (core)
Podium	None
Core	Concrete
Floor slabs	CLT
Program	Residential
External Cladding	Wood
Indoor elements exposed	All the surfaces
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Competition
Influence	Public
Motivations	Sustainability
Architect	architekturagentur, DE
Engineer	Isenmann Ingenieure, DE
Timber Engineer	Isenmann Ingenieure, DE
General Contractor	deep green development, DE
Timber Contractor	Thoma Holz101, DE
Timber Supplier:	
Structural Elements	Thoma Holz101, DE
Floor Elements	Thoma Holz101, DE
Client	IBA Hamburg, DE

SOURCE OF IMAGES

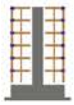
Martin Kunze, architekturagentur



C13

Year Completation	2014
Country	Germany
City	Berlin
Number of Storeys	7
Number Timber Storeys	6

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	3682
Total surface built (f²)	39633
Structural category	 Post-and-Beam timber-concrete-steel (podium-core-steel beams)
Podium	Ground Floor
Core	Concrete
Floor slabs	DLT- Concrete
Program	Mixed Use (residential-office)
External Cladding	Plaster
Indoor elements exposed	Ceiling
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Sustainability
Architect	Kaden-Lager Architekten, DE
Engineer	Pirmin Jung Ingenieure, CH
Timber Engineer	Pirmin Jung Ingenieure, CH
General Contractor	Oa.sys, DE
Timber Contractor	Oa.sys, DE
Timber Supplier:	
Structural Elements	n/a
Floor Elements	n/a
Client	Stiftung Bildung.Werte.Leben, DE

SOURCE OF IMAGES

Bernd Borchardt

Kampa K8

Year Completation	2015
Country	Germany
City	Aalen
Number of Storeys	7
Number Timber Storeys	7

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	3386
Total surface built (f²)	36447
Structural category	Post-and-Beam all-timber
Podium	None
Core	CLT
Floor slabs	CLT
Program	Office
External Cladding	Wood
Indoor elements exposed	All the surfaces
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Sustainability
Architect	Florian Nagler Architekten, DE
Engineer	bauart Konstruktions, DE
Timber Engineer	Stora Enso, FI, AT
General Contractor	Kampa Beteiligungs, DE
Timber Contractor	Stora Enso, FI, AT
Timber Supplier:	
Structural Elements	Stora Enso, FI, SE
Floor Elements	Stora Enso, FI, SE
Client	Kampa Beteiligungs, DE

SOURCE OF IMAGES

Kampa, Mikado-online

Nachverdichtung Speyer

Year Completation	2015
Country	Germany
City	Speyer
Number of Storeys	5
Number Timber Storeys	5

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	1185
Total surface built (f²)	12755
Structural category	Panelised timber-concrete (core)
Podium	None
Core	Concrete
Floor slabs	CLT
Program	Residential
External Cladding	Plaster
Indoor elements exposed	None
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Competition
Influence	Public
Motivations	Sustainability
Architect	Schöne Architekten, Architekturbüro Schnieder, DE
Engineer	Ingenieurbüro von Fragstein, DE
Timber Engineer	Ingenieurbüro von Fragstein, DE
General Contractor	Züblin Timber, DE
Timber Contractor	Züblin Timber, DE
Timber Supplier:	
Structural Elements	Züblin Timber, DE
Floor Elements	Züblin Timber, DE
Client	Gewo Wohnen GmbH, DE

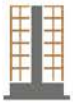
SOURCE OF IMAGES

Züblin Timber

H7

Year Completation	2016
Country	Germany
City	Münster
Number of Storeys	7
Number Timber Storeys	6

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	7000
Total surface built (f²)	75348
Structural category	 Post-and-Beam timber-concrete (podium-core)
Podium	Ground Floor
Core	Concrete
Floor slabs	Glulam-concrete
Program	Office
External Cladding	Metal
Indoor elements exposed	All the surfaces
Building volume	Varying heights

CONTEXTUAL DATA

Type of Commission	n/a
Influence	Private
Motivations	n/a
Architect	Andreas Heupel Architekten, DE
Engineer	Arup, DE
Timber Engineer	Arup, DE
General Contractor	Brüninghoff, DE
Timber Contractor	Brüninghoff, DE
Timber Supplier:	
Structural Elements	Brüninghoff, DE
Floor Elements	Brüninghoff, DE
Client	DESRAD Immobilien, DE

SOURCE OF IMAGES

Andreas Heupel Architekten BDA, Brüninghoff

Wohnen Offenbach

Year Completation	2017
Country	Germany
City	Offenbach
Number of Storeys	5
Number Timber Storeys	4

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	1578
Total surface built (f²)	16986
Structural category	Panelised timber-concrete (podium-core)
Podium	Ground Floor
Core	Concrete
Floor slabs	CLT-concrete
Program	Residential - Social Housing
External Cladding	Wood
Indoor elements exposed	None
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	n/a
Influence	Public
Motivations	Sustainability
Architect	Hirschmueller Architektur, DE
Engineer	Pirmin Jung Ingenieure, CH
Timber Engineer	Pirmin Jung Ingenieure, CH
General Contractor	B&O Wohnungswirtschaft, DE
Timber Contractor	HU-Holzunion, DE
Timber Supplier:	
Structural Elements	HU-Holzunion, DE
Floor Elements	HU-Holzunion, DE
Client	Gemeinnuetzigen Baugesellschaft Offenbach (GBO), DE

SOURCE OF IMAGES

Markus Buck, Cordes Holzbau

Woodie

Year Completation	2017
Country	Germany
City	Hamburg
Number of Storeys	7
Number Timber Storeys	6

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	13510
Total surface built (f²)	145422
Structural category	3D Modular timber-concrete (podium-core)
Podium	Ground Floor
Core	Concrete
Floor slabs	CLT
Program	Student Housing
External Cladding	Wood
Indoor elements exposed	All the surfaces
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Competition
Influence	Private
Motivations	Technical aspects
Architect	Sauerbruch Hutton, DE
Engineer	Merz Kley Partners, AT
Timber Engineer	Merz Kley Partners, AT
General Contractor	PRIMUS developments - Senectus, DE
Timber Contractor	Kaufmann Bausysteme, AT
Timber Supplier:	
Structural Elements	Mayr-Melnhof Holz, AT
Floor Elements	Mayr-Melnhof Holz, AT
Client	PRIMUS developments - Senectus, DE

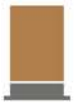
SOURCE OF IMAGES

Kaufmann Bausysteme, Goetz Wrage, Friedhelm Feldhaus

Dantebad

Year Completation	2018
Country	Germany
City	Munich
Number of Storeys	5
Number Timber Storeys	4

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	4630
Total surface built (f²)	49837
Structural category	 Panelised timber-concrete (podium)
Podium	Ground Floor
Core	CLT
Floor slabs	CLT
Program	Residential - Social Housing
External Cladding	Wood
Indoor elements exposed	Ceiling
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	n/a
Influence	Public
Motivations	Technical aspects
Architect	Florian Nagler Architekten, DE
Engineer	r.plan, DE
Timber Engineer	Ingenieurbüro Franz Mitterer-Mang, DE
General Contractor	E. Hönninger, DE
Timber Contractor	Huber & Sohn, DE
Timber Supplier:	
Structural Elements	Stora Enso, FI, SE
Floor Elements	Stora Enso, FI, SE
Client	GEWOFAG Holding, DE

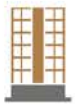
SOURCE OF IMAGES

Stefan Müller-Naumann

Lynarstrasse Berlin

Year Completation	2018
Country	Germany
City	Berlin
Number of Storeys	7
Number Timber Storeys	6

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	7350
Total surface built (f²)	79115
Structural category	 Post-and-Beam timber-concrete (podium)
Podium	Ground Floor
Core	CLT
Floor slabs	CLT
Program	Residential - Social Housing
External Cladding	Wood
Indoor elements exposed	All the surfaces
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	n/a
Influence	Public
Motivations	Sustainability
Architect	Schäferwenningerprojekt, DE
Engineer	Haussler Ingenieure, DE
Timber Engineer	Haussler Ingenieure, DE
General Contractor	HU-Holzunion, DE
Timber Contractor	HU-Holzunion, DE
Timber Supplier:	
Structural Elements	Binderholz, AT
Floor Elements	Binderholz, AT
Client	Wohnungsbaugenossenschaft Am Ostseeplatz, DE

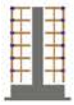
SOURCE OF IMAGES

Bernd Markus Löffelhardt

Famju

Year Completation	2019
Country	Germany
City	Heilbronn
Number of Storeys	5
Number Timber Storeys	4

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	1570
Total surface built (f²)	16899
Structural category	 Post-and-Beam timber-concrete-steel (podium-core-steel beams)
Podium	Ground Floor
Core	Concrete
Floor slabs	CLT
Program	Residential
External Cladding	Plaster
Indoor elements exposed	None
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Public
Motivations	Sustainability
Architect	Kaden-Lager Architekten, DE
Engineer	bauart Konstruktions, DE
Timber Engineer	Ingenieurbüro von Fragstein, DE
General Contractor	Züblin Timber, DE
Timber Contractor	Züblin Timber, DE
Timber Supplier:	
Structural Elements	Züblin Timber, DE
Floor Elements	Züblin Timber, DE
Client	Stadtsiedlung Heilbronn, DE

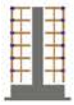
SOURCE OF IMAGES

Bernd Borchardt

SKAIO

Year Completation	2019
Country	Germany
City	Heilbronn
Number of Storeys	10
Number Timber Storeys	9

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	5685
Total surface built (f²)	61193
Structural category	 Post-and-Beam timber-concrete-steel (podium-core-steel beams)
Podium	Ground Floor
Core	Concrete
Floor slabs	CLT
Program	Residential
External Cladding	Metal
Indoor elements exposed	All the surfaces
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Public
Motivations	Sustainability
Architect	Kaden-Lager Architekten, DE
Engineer	bauart Konstruktions, DE
Timber Engineer	Ingenieurbüro von Fragstein, DE
General Contractor	Züblin Timber, DE
Timber Contractor	Züblin Timber, DE
Timber Supplier:	
Structural Elements	Züblin Timber, DE
Floor Elements	Züblin Timber, DE
Client	Stadtsiedlung Heilbronn, DE

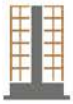
SOURCE OF IMAGES

Bernd Borchardt

WA14 West

Year Completation	2019
Country	Germany
City	Munich
Number of Storeys	7
Number Timber Storeys	6

DESIGN DATA

Number of Buildings	4
Total surface built (m²)	9215
Total surface built (f²)	99190
Structural category	 Post-and-Beam timber-concrete (podium-core)
Podium	Ground Floor
Core	Concrete
Floor slabs	CLT-concrete
Program	Residential - Social Housing
External Cladding	Wood
Indoor elements exposed	None
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Competition
Influence	Public
Motivations	Sustainability
Architect	Rapp Architekten, DE
Engineer	Tragwerke, DE
Timber Engineer	Tragwerke, DE
General Contractor	Müllerblaustein HolzBauWerke, DE
Timber Contractor	Müllerblaustein HolzBauWerke, DE
Timber Supplier:	
Structural Elements	Binderholz, AT
Floor Elements	Hasslacher Nordica Timber, AT
Client	GWG München, DE

SOURCE OF IMAGES

Johann Hartl

WA 15 West

Year Completation	2019
Country	Germany
City	Munich
Number of Storeys	7
Number Timber Storeys	6

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	6920
Total surface built (f²)	74487
Structural category	Panelised timber-concrete (podium-core)
Podium	Ground Floor
Core	Concrete
Floor slabs	CLT
Program	Residential - Social Housing
External Cladding	Wood
Indoor elements exposed	None
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Competition
Influence	Private
Motivations	Sustainability
Architect	H2R-Architekten, DE
Engineer	n/a
Timber Engineer	Huber & Sohn, DE
General Contractor	Huber & Sohn, DE
Timber Contractor	Huber & Sohn, DE
Timber Supplier:	
Structural Elements	Huber & Sohn, DE
Floor Elements	Huber & Sohn, DE
Client	Bauen in Gemeinschaft, DE

SOURCE OF IMAGES

H2R-Architekten, Bauart

Walden 48

Year Completation	2019
Country	Germany
City	Berlin
Number of Storeys	7
Number Timber Storeys	7

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	7500
Total surface built (f²)	80730
Structural category	Panelised timber-concrete (core)
Podium	None
Core	Concrete
Floor slabs	CLT-concrete
Program	Residential - Co-housing
External Cladding	Wood/Metal
Indoor elements exposed	All the surfaces
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Sustainability
Architect	ARGE Scharabi Raupach, DE
Engineer	n/a
Timber Engineer	Rubner, IT
General Contractor	Die HolzBox, DE
Timber Contractor	Rubner, IT
Timber Supplier:	
Structural Elements	Rubner, IT
Floor Elements	Rubner, IT
Client	Baugemeinschaft Walden 48, DE

SOURCE OF IMAGES

Scharabi Raupach, Cohousing Berlin

A.6 Italy

Project (name)	(image)	Storeys (number)	Timber Storeys (number)	Strucutral system (logo)	(category)	Core (material)	Floor Slabs (material)	Total Built Surface (m2)	Program (type)	Facade cladding (material)	Structural timber exposure (category)
Residence Alexander		6	6		Panelised timber-concrete (core)	Concrete	CLT	4900	Residential	Plaster	None
Cenni di Cambiamento		9	9		Panelised all-timber	CLT	CLT	30325	Residential-Social Housing	Plaster	None
Panorama Giustinelli		7	7		Post-and-Beam timber-concrete (core)	Concrete	Glulam	4500	Residential	Plaster	None
Marina verde		7	7		Post-and-Beam timber-concrete (core)	Concrete	Glulam	14900	Hotel	Plaster	None
Multipiano Coppito		5	4		Panelised timber-concrete (podium-core)	Concrete	CLT	1200	Residential	Plaster	None
Firenze Ex-Longinotti		6	6		Panelised all-timber	CLT	CLT	5200	Residential - Social Housing	Plaster	None
Palazzina 5 piani		5	4		Panelised timber-concrete (podium-core)	Concrete	CLT	1350	Residential - Social Housing	Plaster	None
30 Wood House		6	6		Panelised all-timber	CLT	CLT	520	Residential	Plaster	None
Hotel Nautilus		8	7		Panelised timber-concrete (podium)	CLT	CLT	2458	Hotel	Plaster	Ceiling
Residenza Mayer		5	5		3D Modular timber-concrete (core)	Concrete	CLT	4350	Student Housing	Cement based	None
5 per 5+1		5	5		Panelised all-timber	CLT	CLT	5500	Residential - Social Housing	Plaster	None
GreenTorino		7	6		Panelised timber-concrete (podium)	CLT	CLT	930	Residential	Plaster	None
Social Housing Vado Ligure		5	4		Panelised timber-concrete (podium)	CLT	CLT	1750	Residential - Social Housing	Plaster	n/a

Residence Alexander

Year Completation	2012
Country	Italy
City	Acquila
Number of Storeys	6
Number Timber Storeys	6

DESIGN DATA

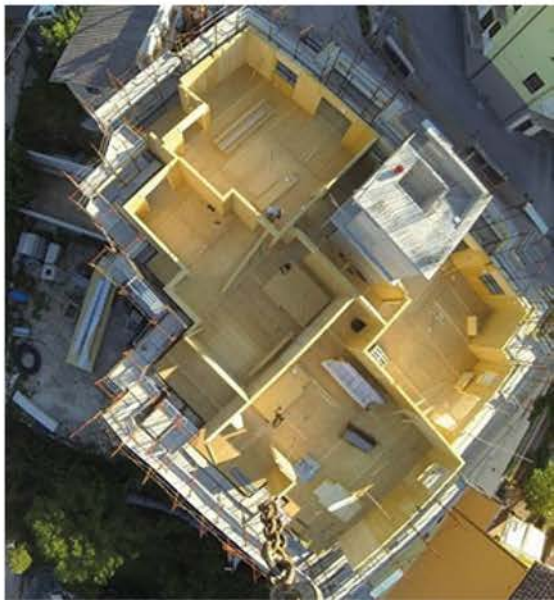
Number of Buildings	1
Total surface built (m²)	4900
Total surface built (f²)	52744
Structural category	Panelised timber-concrete (core)
Podium	None
Core	Concrete
Floor slabs	CLT
Program	Residential
External Cladding	Plaster
Indoor elements exposed	None
Building volume	Pitched roof

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Technical aspects
Architect	Arch. Sebastiano Calabrò, IT
Engineer	Idsingegneria Agostino Presutti, IT
Timber Engineer	Forest legnami, IT
General Contractor	n/a
Timber Contractor	Forest legnami, IT
Timber Supplier:	
Structural Elements	Binderholz, AT
Floor Elements	Binderholz, AT
Client	GEIM, IT

SOURCE OF IMAGES

Idsingegneria Agostino Presutti



Cenni di Cambiamento

Year Completation	2013
Country	Italy
City	Milan
Number of Storeys	9
Number Timber Storeys	9

DESIGN DATA

Number of Buildings	4
Total surface built (m²)	30325
Total surface built (f²)	326418
Structural category	Panelised all-timber
Podium	None
Core	CLT
Floor slabs	CLT
Program	Residential-Social Housing
External Cladding	Plaster
Indoor elements exposed	None (few ceilings)
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Competition
Influence	Public/Private
Motivations	Sustainability
Architect	Rossiprodi Associati, IT
Engineer	Borlini& Zanini, CH
Timber Engineer	Borlini& Zanini, CH
General Contractor	Carron spa, IT
Timber Contractor	Service Legno, IT - MAK Building, AT
Timber Supplier:	
Structural Elements	Stora Enso, FI, SE
Floor Elements	Stora Enso, FI, SE
Client	Polaris SGR - Comune di Milano, IT

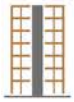
SOURCE OF IMAGES

Rossiprodi Associati, sg-gallerylive.it, Structural | L'Edilizia

Panorama Giustinelli

Year Completation	2013
Country	Italy
City	Trieste
Number of Storeys	7
Number Timber Storeys	7

DESIGN DATA

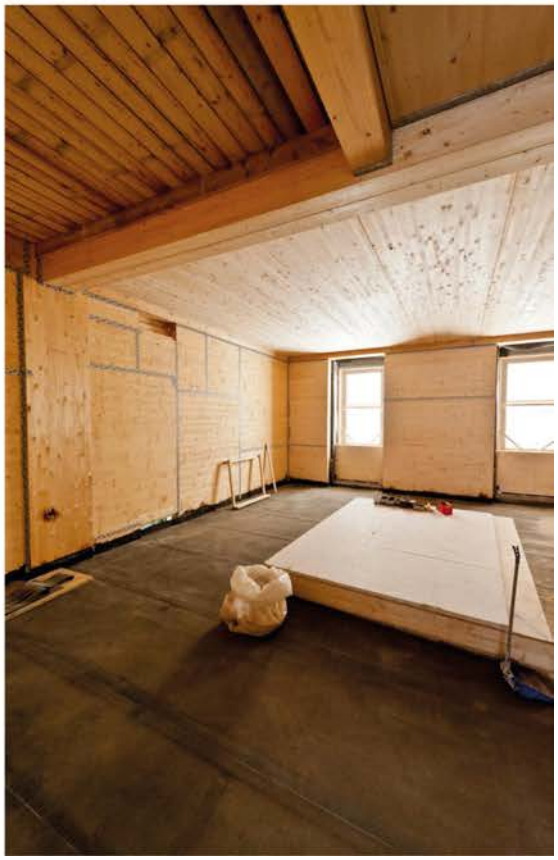
Number of Buildings	1
Total surface built (m²)	4500
Total surface built (f²)	48438
Structural category	 Post-and-Beam timber-concrete (core)
Podium	None
Core	Concrete
Floor slabs	Glulam
Program	Residential
External Cladding	Plaster
Indoor elements exposed	None
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Sustainability
Architect	Epoca - Luciano Lazzari Architetto, IT
Engineer	BDL Progetti, IT
Timber Engineer	Rubner, IT
General Contractor	Epoca, IT
Timber Contractor	Rubner, IT
Timber Supplier:	
Structural Elements	Rubner, IT
Floor Elements	Rubner, IT
Client	Epoca, IT

SOURCE OF IMAGES

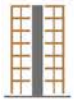
Epoca srl, arketipomagazine.it



Marina verde

Year Completation	2014
Country	Italy
City	Caorle
Number of Storeys	7
Number Timber Storeys	7

DESIGN DATA

Number of Buildings	2
Total surface built (m²)	14900
Total surface built (f²)	160384
Structural category	 Post-and-Beam timber-concrete (core)
Podium	None
Core	Concrete
Floor slabs	Glulam
Program	Hotel
External Cladding	Plaster
Indoor elements exposed	None
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Sustainability
Architect	Simone Micheli – architectural hero, IT
Engineer	Studio P&B Associati, IT
Timber Engineer	Rubner, IT
General Contractor	n/a
Timber Contractor	Rubner, IT
Timber Supplier:	
Structural Elements	Rubner, IT
Floor Elements	Rubner, IT
Client	Marina Verde, IT

SOURCE OF IMAGES

Rubner, impresedilinews.it

Multipiano Coppito

Year Completation	2014
Country	Italy
City	Coppito
Number of Storeys	5
Number Timber Storeys	4

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	1200
Total surface built (f²)	12917
Structural category	Panelised timber-concrete (podium-core)
Podium	Ground Floor
Core	Concrete
Floor slabs	CLT
Program	Residential
External Cladding	Plaster
Indoor elements exposed	None
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Technical aspects
Architect	n/a
Engineer	Idsingegneria Agostino Presutti, IT
Timber Engineer	Forest legnami, IT
General Contractor	Vittorini Emidio Costruzioni, IT
Timber Contractor	Forest legnami, IT
Timber Supplier:	
Structural Elements	Binderholz, AT
Floor Elements	Binderholz, AT
Client	Vittorini Emidio Costruzioni, IT

SOURCE OF IMAGES

gruppoforest.it, Idsingegneria Agostino Presutti

Firenze Ex-Longinotti

Year Completation	2015
Country	Italy
City	Firenze
Number of Storeys	6
Number Timber Storeys	6

DESIGN DATA

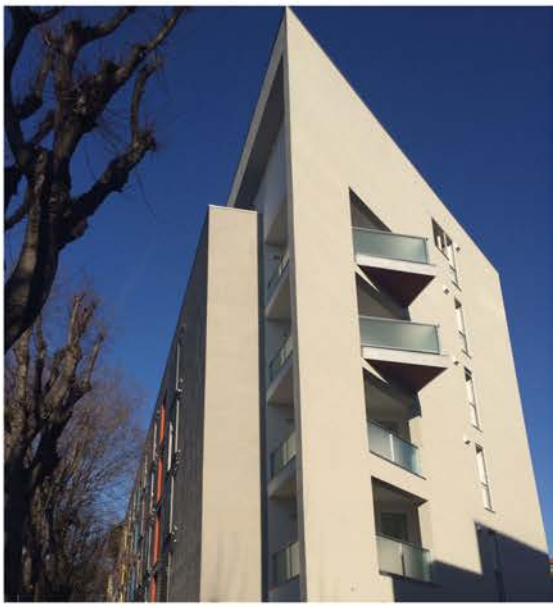
Number of Buildings	1
Total surface built (m²)	5200
Total surface built (f²)	20880
Structural category	Panelised all-timber
Podium	None
Core	CLT
Floor slabs	CLT
Program	Residential - Social Housing
External Cladding	Plaster
Indoor elements exposed	None
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Public
Motivations	Sustainability
Architect	Casa S.p.a., IT
Engineer	Casa S.p.a., IT
Timber Engineer	Dedalegno, IT
General Contractor	Imola Legno - Campigli Legnami - Elettra Impianti, IT
Timber Contractor	MAK Building, AT
Timber Supplier:	
Structural Elements	Stora Enso, FI, SE
Floor Elements	Stora Enso, FI, SE
Client	Comune di Firenze, IT

SOURCE OF IMAGES

Casa spa, Matteo Aricò



Palazzina 5 piani

Year Completation	2015
Country	Italy
City	Trento
Number of Storeys	5
Number Timber Storeys	4

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	1350
Total surface built (f²)	14531
Structural category	Panelised timber-concrete (podium-core)
Podium	Ground Floor
Core	Concrete
Floor slabs	CLT
Program	Residential - Social Housing
External Cladding	Plaster
Indoor elements exposed	None
Building volume	Pitched roof

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Public
Motivations	Sustainability
Architect	Alberto Cristofolini Architetto, IT
Engineer	EW-Engineering Works, IT
Timber Engineer	EW-Engineering Works, IT
General Contractor	Btd Servizi - Legno più case, IT
Timber Contractor	Gruppo Paterno (Xlam Dolomiti and Legno più case), IT
Timber Supplier:	
Structural Elements	XLam Dolomiti, IT
Floor Elements	XLam Dolomiti, IT
Client	Itea, IT - Canadian social housing Quebec Societé D'Habitation, CA

SOURCE OF IMAGES

EW-Engineering Works

30 Wood House

Year Completation	2017
Country	Italy
City	Modena
Number of Storeys	6
Number Timber Storeys	6

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	520
Total surface built (f²)	5597
Structural category	Panelised all-timber
Podium	None
Core	CLT
Floor slabs	CLT
Program	Residential
External Cladding	Plaster
Indoor elements exposed	None
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Sustainability
Architect	Fabbricart Architetti Associati, IT
Engineer	Ergodomus, IT
Timber Engineer	Ergodomus, IT
General Contractor	n/a
Timber Contractor	Foresti, IT
Timber Supplier:	
Structural Elements	Mayr-Melnhof Holz, AT
Floor Elements	Mayr-Melnhof Holz, AT
Client	Gualdi, IT

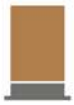
SOURCE OF IMAGES

azeroweb.com, Ergodomus

Hotel Nautilus

Year Completation	2017
Country	Italy
City	Pesaro
Number of Storeys	8
Number Timber Storeys	7

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	2458
Total surface built (f²)	26458
Structural category	 Panelised timber-concrete (podium)
Podium	Ground Floor
Core	CLT
Floor slabs	CLT
Program	Hotel
External Cladding	Plaster
Indoor elements exposed	Ceiling
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Technical aspects
Architect	Architetto Marco Gaudenzi, IT
Engineer	Ing. Marchetti Rossi Attilio, IT
Timber Engineer	Stora Enso
General Contractor	Centrolegno di Fano, IT
Timber Contractor	MAK Building, AT
Timber Supplier:	
Structural Elements	Stora Enso, FI, SE
Floor Elements	Stora Enso, FI, SE
Client	Eden Viaggi, IT

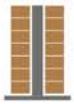
SOURCE OF IMAGES

Mak Building, Hotel Nautilus, proHolz

Residenza Mayer

Year Completation	2017
Country	Italy
City	Trento
Number of Storeys	5
Number Timber Storeys	5

DESIGN DATA

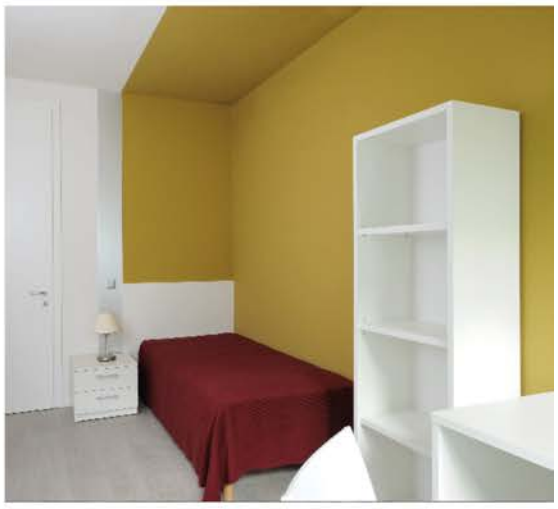
Number of Buildings	1
Total surface built (m²)	4350
Total surface built (f²)	46823
Structural category	 3D Modular timber-concrete (core)
Podium	None
Core	Concrete
Floor slabs	CLT
Program	Student Housing
External Cladding	Cement based
Indoor elements exposed	None
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Public
Motivations	Sustainability
Architect	Studio bbs architetti associati, IT
Engineer	Prof. Ario Ceccotti - Ing. Mauro Croce, IT
Timber Engineer	Prof. Ario Ceccotti - Ing. Mauro Croce, IT
General Contractor	Essepi, IT
Timber Contractor	Essepi, IT
Timber Supplier:	
Structural Elements	Essepi, IT
Floor Elements	Essepi, IT
Client	Opera Universitaria della Provincia Autonoma di Trento

SOURCE OF IMAGES

operauni.tn.it, toxonspa.it, Paolo Simeone | DUOPUU



5 per 5+1

Year Completation	2018
Country	Italy
City	Trieste
Number of Storeys	5
Number Timber Storeys	5

DESIGN DATA

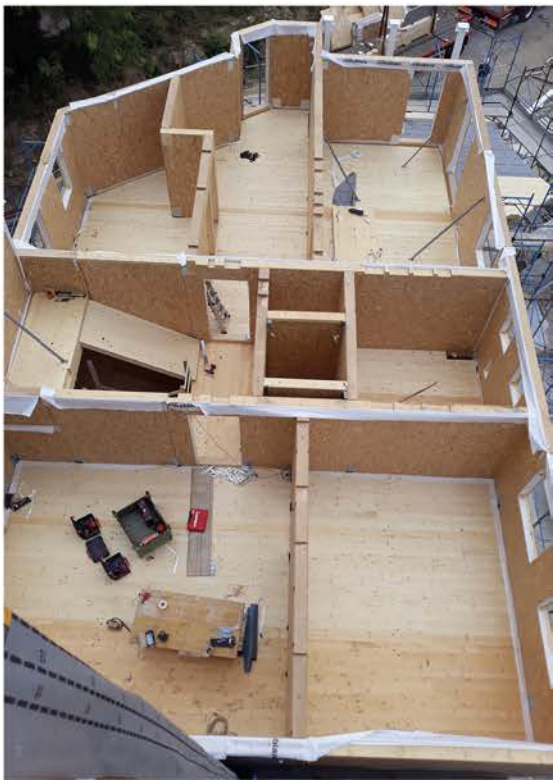
Number of Buildings	5
Total surface built (m²)	5500
Total surface built (f²)	11840
Structural category	Panelised all-timber
Podium	None
Core	CLT
Floor slabs	CLT
Program	Residential - Social Housing
External Cladding	Plaster
Indoor elements exposed	None
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Public
Motivations	Sustainability
Architect	n/a
Engineer	Bodino, IT
Timber Engineer	Bodino, IT
General Contractor	Riccesi, IT
Timber Contractor	Bodino, IT
Timber Supplier:	
Structural Elements	KLH, AT - Xlam Dolomiti, IT
Floor Elements	KLH, AT - Xlam Dolomiti, IT
Client	ATER Trieste, IT

SOURCE OF IMAGES

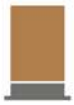
Ing. Claudio Genero, Bodino



GreenTorino

Year Completation	2019
Country	Italy
City	Torino
Number of Storeys	7
Number Timber Storeys	6

DESIGN DATA

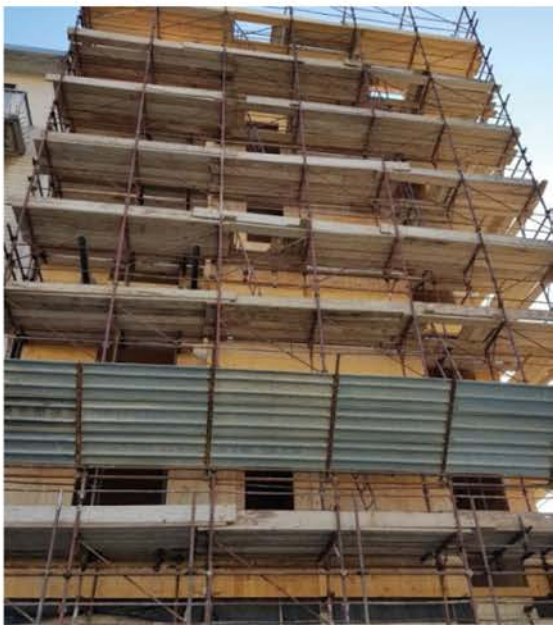
Number of Buildings	1
Total surface built (m²)	930
Total surface built (f²)	10011
Structural category	 Panelised timber-concrete (podium)
Podium	Ground Floor
Core	CLT
Floor slabs	CLT
Program	Residential
External Cladding	Plaster
Indoor elements exposed	None
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Sustainability
Architect	Maurizio Salerno Architetto
Engineer	Ing. Fabio Mosca, IT
Timber Engineer	Tecnici.eu, IT
General Contractor	Isi - La Quercia Bioedilizia, IT
Timber Contractor	MAK Building, AT
Timber Supplier:	
Structural Elements	Stora Enso, FI, SE
Floor Elements	Stora Enso, FI, SE
Client	Immobiliare Salerno, IT

SOURCE OF IMAGES

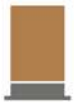
Knauf, toarchmagazine.it



Social Housing Vado Ligure

Year Completation	2019
Country	Italy
City	Vado Ligure
Number of Storeys	5
Number Timber Storeys	4

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	1750
Total surface built (f²)	18837
Structural category	 Panelised timber-concrete (podium)
Podium	Ground Floor
Core	CLT
Floor slabs	CLT
Program	Residential - Social Housing
External Cladding	Plaster
Indoor elements exposed	n/a
Building volume	Regular

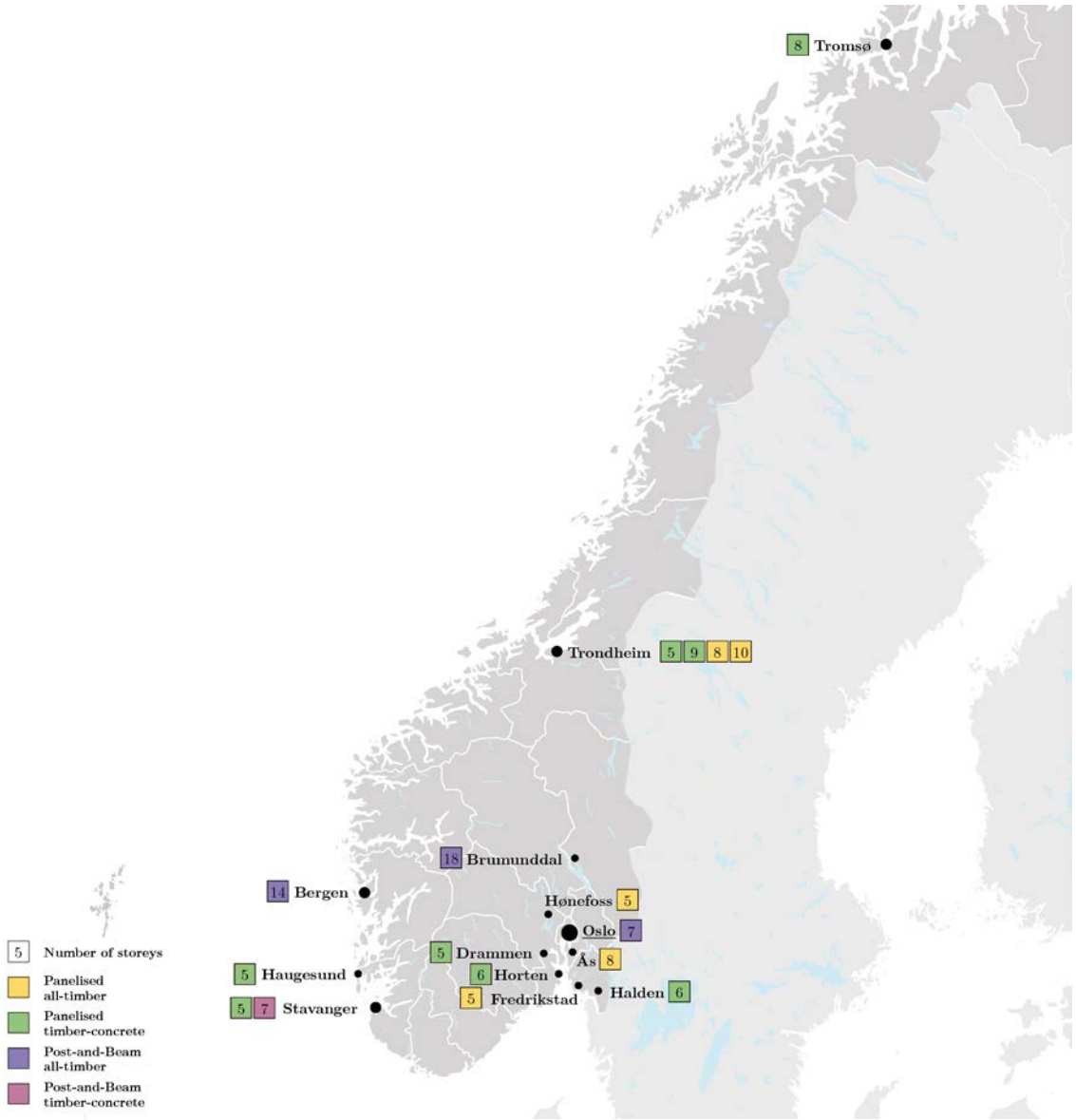
CONTEXTUAL DATA

Type of Commission	Direct
Influence	Public/Private
Motivations	Sustainability
Architect	5-1AA, IT
Engineer	EW-Engineering Works, IT
Timber Engineer	EW-Engineering Works, IT
General Contractor	Gandelli Group, IT, CH
Timber Contractor	Gandelli Group, IT, CH
Timber Supplier:	
Structural Elements	Stora Enso, FI, SE
Floor Elements	Stora Enso, FI, SE
Client	Fondazione Domus - Comune Vado Ligure, IT

SOURCE OF IMAGES

La Stampa, Gandelligroup

A.7 Norway

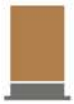

8 Tromsø
Trondheim 5 9 8 10
18 Brumunddal
14 Bergen
Hønefoss 5
Oslo 7
5 Drammen
Ås 8
5 Haugesund
6 Horten
5 Fredrikstad
Halden 6
5 7 Stavanger
5 Number of storeys
Panelised all-timber
Panelised timber-concrete
Post-and-Beam all-timber
Post-and-Beam timber-concrete

Project (name)	(image)	Storeys (number)	Timber Storeys (number)	Strucutral system (logo)	(category)	Core (material)	Floor Slabs (material)	Total Built Surface (m2)	Program (type)	Facade cladding (material)	Structural timber exposure (category)
Svartlamoen Housing		5	4		Platform timber-concrete (podium)	CLT	CLT	1080	Residential - Social Housing	Wood	All the surfaces
Egnes Park		5	5		Platform timber-concrete (core)	Concrete	LVL box elements	13000	Residential	Wood	All the surfaces
Palisaden		8	8		Platform all-timber	CLT	CLT	4000	Student Housing	Wood/ Metal	Walls
Treet		14	14		Post-and-beam all-timber (external bracing)	CLT	LVL box elements	5830	Residential	Metal	Columns and beams
Sørhauggate		5	4		Platform timber-concrete (podium)	CLT	CLT	1960	Student Housing	Wood	Walls
Studentboliger Remmen		6	5		Platform timber-concrete (podium)	CLT	CLT	9552	Student Housing	Wood/ Metal	Walls
Bjølstad Studentboliger		5	5		Platform all-timber	CLT	CLT	5656	Student Housing	Wood/ Metal	All the surfaces
Moholt 50/50		9	8		Platform timber-concrete (podium)	CLT	CLT	21800	Student Housing	Wood	All the surfaces
Ringerike Campus		5	5		Platform all-timber	CLT	CLT	7500	Student Housing	Wood	Walls
Dramsvegen		8	7		Platform timber-concrete (podium)	CLT	CLT	25000	Student Housing	Wood/Metal	Walls
Øvre Sund		5	4		Platform timber-concrete (podium)	CLT	CLT	5500	Student Housing	Wood/ Metal	All the surfaces
Fagerlund studenthybler		6	4		Platform timber-concrete (podium)	CLT	CLT	9000	Student Housing	Wood	Walls
Kringsjå studentby		10	10		Platform all-timber	CLT	CLT	13106	Student Housing	Wood	Walls
Maskinparken TRE		8	8		Platform all-timber	CLT	CLT	4135	Residential	Wood	None
Bjergsted Financial Park		7	7		Post and beam timber-concrete (core)	Concrete	CLT	13400	Office	Curtain wall	All the surfaces
Mjøstårnet		18	18		Post-and-beam all-timber (external bracing)	CLT	LVL box elements	11300	Mixed Use (residential-other)	Wood	Columns and beams
Valle Wood		7	7		Post-and-beam all-timber	CLT	CLT-concrete	6700	Office	Wood	All the surfaces

Svartlamoen Housing

Year Completation	2005
Country	Norway
City	Trondheim
Number of Storeys	5
Number Timber Storeys	4

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	1080
Total surface built (f²)	11625
Structural category	 Panelised timber-concrete (podium)
Podium	Ground Floor
Core	CLT
Floor slabs	CLT
Program	Residential - Social Housing
External Cladding	Wood
Indoor elements exposed	All the surfaces
Building volume	Pitched roof

CONTEXTUAL DATA

Type of Commission	Competition
Influence	Public
Motivations	Sustainability
Architect	Brendeland & Kristoffersen arkitekter, NO
Engineer	Reinersten Engineering, NO
Timber Engineer	Reinersten Engineering, NO
General Contractor	Stjern, NO
Timber Contractor	Santner, AT
Timber Supplier:	
Structural Elements	Santner, AT
Floor Elements	Santner, AT
Client	Svartlamoen housing trust, NO

SOURCE OF IMAGES

Jeroen Musch

Egnes Park

Year Completation	2010
Country	Norway
City	Stavanger
Number of Storeys	5
Number Timber Storeys	5

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	13000
Total surface built (f²)	139932
Structural category	Panelised timber-concrete (core)
Podium	None
Core	Concrete
Floor slabs	Box Elements
Program	Residential
External Cladding	Wood
Indoor elements exposed	All the surfaces
Building volume	Pitched roof

CONTEXTUAL DATA

Type of Commission	Competition
Influence	Public/Private
Motivations	Sustainability
Architect	Onix, NL - HLM arkitektur - NAL, NO
Engineer	Moelven, NO
Timber Engineer	Moelven, NO
General Contractor	Tore Ravndal, NO
Timber Contractor	n/a
Timber Supplier:	
Structural Elements	Moelven, NO
Floor Elements	Moelven, NO
Client	Svein Aase, NO

SOURCE OF IMAGES

Moelven, onix.nl, fourthdoor.org

Palisaden

Year Completation	2013
Country	Norway
City	Ås
Number of Storeys	8
Number Timber Storeys	8

DESIGN DATA

Number of Buildings	2
Total surface built (m²)	4000
Total surface built (f²)	43056
Structural category	Panelised all-timber
Podium	None
Core	CLT
Floor slabs	CLT
Program	Student Housing
External Cladding	Wood/Metal
Indoor elements exposed	Walls
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	n/a
Influence	Public
Motivations	Sustainability
Architect	BAS Arkitekter, NO
Engineer	Høyer Finseth , NO
Timber Engineer	Høyer Finseth, NO - iTRE, NO
General Contractor	Veidekke , NO
Timber Contractor	Raimund Baumgartner, AT
Timber Supplier:	
Structural Elements	Mayr-Melnhof Holz, AT
Floor Elements	Mayr-Melnhof Holz, AT
Client	Student Service Foundation Ås, NO

SOURCE OF IMAGES

BAS Arkitekter

Treet

Year Completation	2014
Country	Norway
City	Bergen
Number of Storeys	14
Number Timber Storeys	14

DESIGN DATA

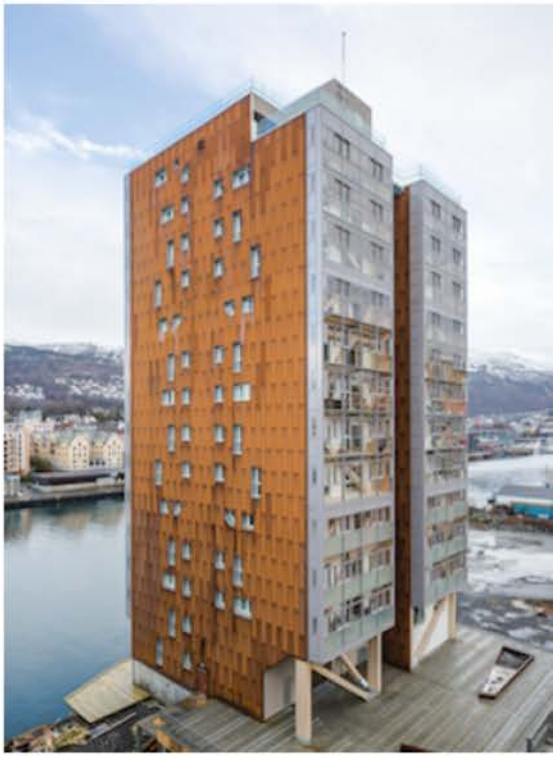
Number of Buildings	1
Total surface built (m²)	5830
Total surface built (f²)	62754
Structural category	Post-and-Beam all-timber (external bracing)
Podium	None
Core	CLT
Floor slabs	LVL (some concrete floors)
Program	Residential
External Cladding	Metal
Indoor elements exposed	Columns and beams
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Technical aspects
Architect	Artec Architecture, NO
Engineer	Sweco, INT
Timber Engineer	Moelven, NO
General Contractor	n/a
Timber Contractor	Moelven, NO
Timber Supplier:	
Structural Elements	Moelven, NO
Floor Elements	Moelven, NO - Züblin Timber, DE
Client	Bergen og omegn boligbyggelag, NO

SOURCE OF IMAGES

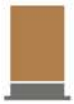
Sweco, Artec



Sørhauggate

Year Completation	2015
Country	Norway
City	Haugesund
Number of Storeys	5
Number Timber Storeys	4

DESIGN DATA

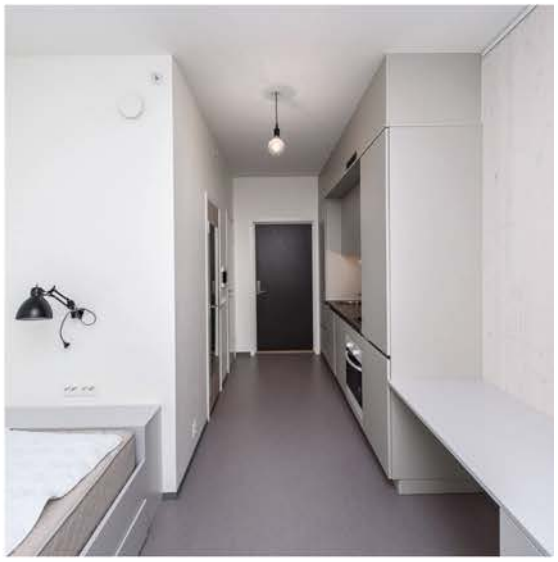
Number of Buildings	1
Total surface built (m²)	1960
Total surface built (f²)	21097
Structural category	 Panelised timber-concrete (podium)
Podium	Ground Floor
Core	CLT
Floor slabs	CLT
Program	Student Housing
External Cladding	Wood
Indoor elements exposed	Walls
Building volume	Pitched roof

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Public
Motivations	Technical aspects
Architect	Helen&Hard, NO - PPAG Architekten, AT
Engineer	n/a
Timber Engineer	Multiconsult - Høyer Finseth - iTRE, NO
General Contractor	Veidekke , NO
Timber Contractor	Woodcon, NO, SE, AT
Timber Supplier:	
Structural Elements	Stora Enso, FI, SE
Floor Elements	Stora Enso, FI, SE
Client	Student Welfare Organization of Stord Haugesund, NO

SOURCE OF IMAGES

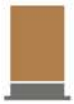
helenhard, hybel.no



Studentboliger Remmen

Year Completation	2015
Country	Norway
City	Halden
Number of Storeys	6
Number Timber Storeys	5

DESIGN DATA

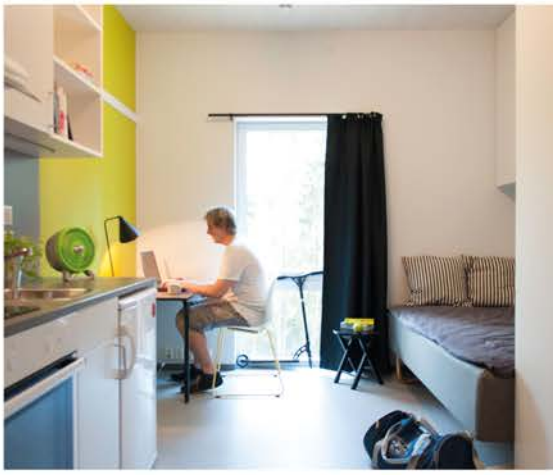
Number of Buildings	4
Total surface built (m²)	9552
Total surface built (f²)	102818
Structural category	 Panelised timber-concrete (podium)
Podium	Ground Floor
Core	CLT
Floor slabs	CLT
Program	Student Housing
External Cladding	Wood/Metal
Indoor elements exposed	Walls
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	n/a
Influence	Public
Motivations	Sustainability
Architect	BAS Arkitekter, NO
Engineer	n/a
Timber Engineer	iTRE, NO
General Contractor	Ove Skår, NO
Timber Contractor	Woodcon, NO, SE, AT
Timber Supplier:	
Structural Elements	Stora Enso, FI, SE
Floor Elements	Stora Enso, FI, SE
Client	Student Association in Østfold (SiØ), NO

SOURCE OF IMAGES

BAS Arkitekter, ove-skaar.no



Bjølstad Studentboliger

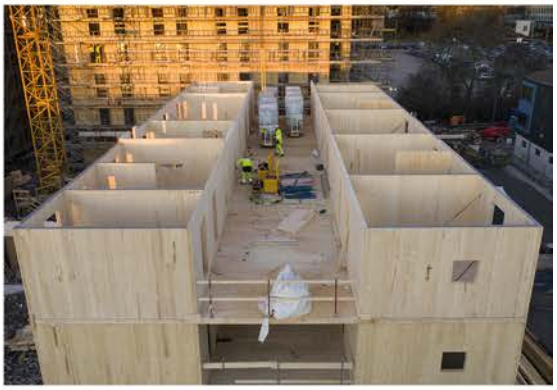
Year Completation	2016
Country	Norway
City	Fredrikstad
Number of Storeys	5
Number Timber Storeys	5

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	5656
Total surface built (f²)	60881
Structural category	Panelised all-timber
Podium	None
Core	CLT
Floor slabs	CLT
Program	Student Housing
External Cladding	Wood/Metal
Indoor elements exposed	All the surfaces
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	n/a
Influence	Public
Motivations	Sustainability
Architect	BAS Arkitekter, NO
Engineer	n/a
Timber Engineer	iTRE, NO
General Contractor	Ove Skår, NO
Timber Contractor	n/a
Timber Supplier:	
Structural Elements	Binderholz, AT
Floor Elements	Binderholz, AT
Client	Student Association in Østfold (SiØ), NO



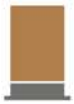
SOURCE OF IMAGES

Erik Burås, Studio B13, sorliepro.no, straye.no

Moholt 50/50

Year Completation	2016
Country	Norway
City	Trondheim
Number of Storeys	9
Number Timber Storeys	8

DESIGN DATA

Number of Buildings	5
Total surface built (m²)	21800
Total surface built (f²)	234655
Structural category	 Panelised timber-concrete (podium)
Podium	Ground Floor
Core	CLT
Floor slabs	CLT
Program	Student Housing
External Cladding	Wood
Indoor elements exposed	All the surfaces
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	n/a
Influence	Public
Motivations	Sustainability
Architect	MDH Arkitekter, NO
Engineer	Moelven, NO
Timber Engineer	Moelven, NO
General Contractor	Veidekke , NO
Timber Contractor	Woodcon, NO, SE, AT
Timber Supplier:	
Structural Elements	Moelven, NO - Stora Enso FI, SE
Floor Elements	Stora Enso, FI, SE
Client	Studentsamskipnaden i Trondheim, NO

SOURCE OF IMAGES

Ivan Brodey, Studentsamskipnaden og MDH arkitekter

Ringerike Campus

Year Completation	2016
Country	Norway
City	Hønefoss
Number of Storeys	5
Number Timber Storeys	5

DESIGN DATA

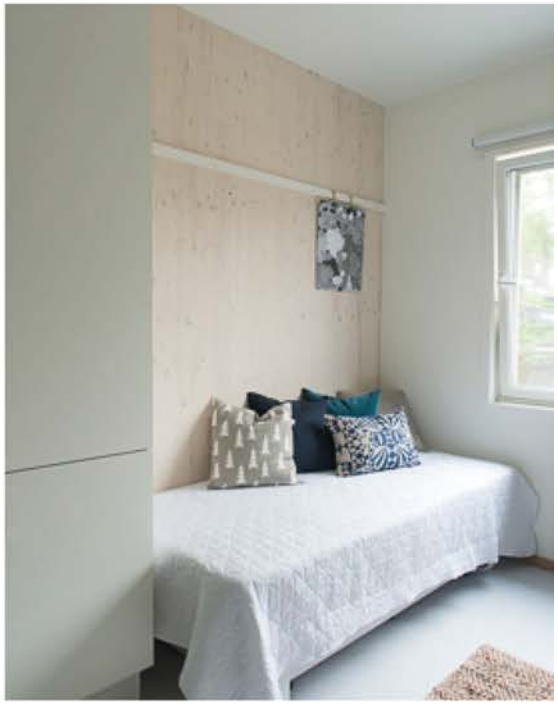
Number of Buildings	2
Total surface built (m²)	7500
Total surface built (f²)	80730
Structural category	Panelised all-timber
Podium	None
Core	CLT
Floor slabs	CLT
Program	Student Housing
External Cladding	Wood
Indoor elements exposed	Walls
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	n/a
Influence	Public
Motivations	Sustainability
Architect	Code, NO
Engineer	WSP Engineering, NO
Timber Engineer	WSP Engineering, NO
General Contractor	Veidekke , NO
Timber Contractor	Woodcon, NO, SE, AT
Timber Supplier:	
Structural Elements	Stora Enso, FI, SE
Floor Elements	Stora Enso, FI, SE
Client	Studentsamskipnaden sørøst-Norge, NO

SOURCE OF IMAGES

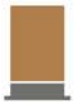
ssn.no, Veidekke



Dramsvegen

Year Completation	2017
Country	Norway
City	Tromsø
Number of Storeys	8
Number Timber Storeys	7

DESIGN DATA

Number of Buildings	4
Total surface built (m²)	25000
Total surface built (f²)	269100
Structural category	 Panelised timber-concrete (podium)
Podium	Ground Floor
Core	CLT
Floor slabs	CLT
Program	Student Housing
External Cladding	Wood/Metal
Indoor elements exposed	Walls
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	n/a
Influence	Public
Motivations	Sustainability
Architect	AT Plan \& Arkitektur, NO
Engineer	n/a
Timber Engineer	Büro Koppelhuber, AT - Hoyer Finseth, NO
General Contractor	Econor, NO
Timber Contractor	Woodcon, NO, SE, AT - Baumgartner, AT
Timber Supplier:	
Structural Elements	Stora Enso, FI, SE
Floor Elements	Stora Enso, FI, SE
Client	Norges Arktiske Studentskipnad, NO

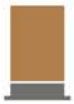
SOURCE OF IMAGES

itromso.no, Trygve Andreassen, Josef Koppelhuber

Øvre Sund

Year Completation	2017
Country	Norway
City	Drammen
Number of Storeys	5
Number Timber Storeys	4

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	5500
Total surface built (f²)	59202
Structural category	 Panelised timber-concrete (podium)
Podium	Ground Floor
Core	CLT
Floor slabs	CLT
Program	Student Housing
External Cladding	Wood/Metal
Indoor elements exposed	All the surfaces
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	n/a
Influence	Public
Motivations	Sustainability
Architect	Code, NO
Engineer	WSP Engineering, NO
Timber Engineer	WSP Engineering, NO
General Contractor	Veidekke , NO
Timber Contractor	Woodcon, NO, SE, AT
Timber Supplier:	
Structural Elements	Stora Enso, FI, SE
Floor Elements	Stora Enso, FI, SE
Client	Studentsamskipnaden sørøst-Norge, NO

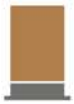
SOURCE OF IMAGES

Birgitte Simensen Berg, SSN Drammen

Fagerlund studenthybler

Year Completation	2018
Country	Norway
City	Horten
Number of Storeys	6
Number Timber Storeys	4

DESIGN DATA

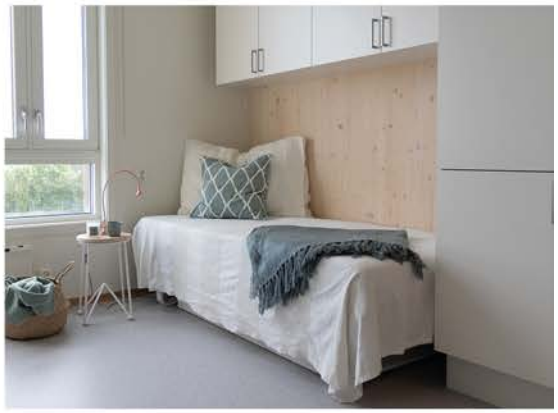
Number of Buildings	1
Total surface built (m²)	9000
Total surface built (f²)	96876
Structural category	 Panelised timber-concrete (podium)
Podium	Up to 1 floor
Core	CLT
Floor slabs	CLT
Program	Student Housing
External Cladding	Wood
Indoor elements exposed	Walls
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	n/a
Influence	Public
Motivations	Sustainability
Architect	Code, NO
Engineer	n/a
Timber Engineer	n/a
General Contractor	Veidekke , NO
Timber Contractor	Woodcon, NO, SE, AT
Timber Supplier:	
Structural Elements	Stora Enso, FI, SE
Floor Elements	Stora Enso, FI, SE
Client	Studentsamskipnaden sørøst-Norge, NO

SOURCE OF IMAGES

Vjus AS, ssn.no



Kringsjå studentby

Year Completation	2018
Country	Norway
City	Trondheim
Number of Storeys	10
Number Timber Storeys	10

DESIGN DATA

Number of Buildings	2
Total surface built (m²)	13106
Total surface built (f²)	141073
Structural category	Panelised all-timber
Podium	None
Core	CLT
Floor slabs	CLT
Program	Student Housing
External Cladding	Wood
Indoor elements exposed	Walls
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Competition
Influence	Public
Motivations	Sustainability
Architect	AT Plan & Arkitektur, NO
Engineer	n/a
Timber Engineer	iTRE AS, NO
General Contractor	Ove Skår, NO
Timber Contractor	n/a
Timber Supplier:	
Structural Elements	Mayr-Melnhof Holz, AT
Floor Elements	Mayr-Melnhof Holz, AT
Client	Univeristy Oslo, NO

SOURCE OF IMAGES

SiO, Mayr-Melnhof Holz

Maskinparken TRE

Year Completation	2018
Country	Norway
City	Trondheim
Number of Storeys	8
Number Timber Storeys	8

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	4135
Total surface built (f²)	44509
Structural category	Panelised all-timber
Podium	None
Core	CLT
Floor slabs	CLT
Program	Residential
External Cladding	Wood
Indoor elements exposed	None
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Technical aspects
Architect	HUS Arkitekter, NO
Engineer	WSP Engineering, NO
Timber Engineer	WSP Engineering, NO
General Contractor	Veidekke , NO
Timber Contractor	Woodcon, NO, SE, AT
Timber Supplier:	
Structural Elements	Stora Enso, FI, SE
Floor Elements	Stora Enso, FI, SE
Client	Lilleby Eiendom, NO

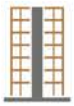
SOURCE OF IMAGES

Lilleby, Veidekke

Bjergsted Financial Park

Year Completation	2019
Country	Norway
City	Stavanger
Number of Storeys	7
Number Timber Storeys	7

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	13400
Total surface built (f²)	144238
Structural category	 Post-and-Beam timber-concrete (core)
Podium	None
Core	Concrete
Floor slabs	CLT
Program	Office
External Cladding	Curtain wall
Indoor elements exposed	All the surfaces
Building volume	Irregular

CONTEXTUAL DATA

Type of Commission	Competition
Influence	Private
Motivations	Technical aspects
Architect	Helen&Hard - Sahaa, NO
Engineer	Degree of Freedom, INT - Creation Holz, CH
Timber Engineer	Degree of Freedom, INT - Creation Holz, CH
General Contractor	Veidekke , NO
Timber Contractor	Block Berge Bygg, NO
Timber Supplier:	
Structural Elements	Hess Timber, DE
Floor Elements	Moelven - Faber Bygg, NO - Pollmeier, DE
Client	SpareBank - Finansparken Bjergstad, NO

SOURCE OF IMAGES

Sindre Ellingsen, Jan Inge Haga

Mjøstårnet

Year Completation	2019
Country	Norway
City	Brumunddal
Number of Storeys	18
Number Timber Storeys	18

DESIGN DATA

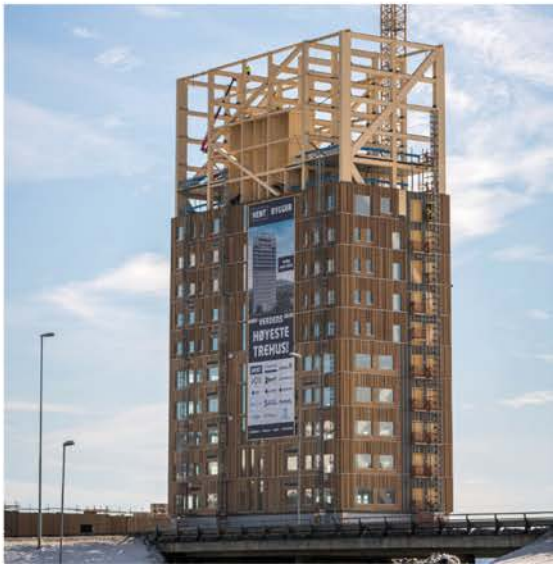
Number of Buildings	1
Total surface built (m²)	11300
Total surface built (f²)	121633
Structural category	Post-and-Beam all-timber (external bracing)
Podium	None
Core	CLT
Floor slabs	LVL (some floors concrete)
Program	Mixed Use (residential-other)
External Cladding	Wood
Indoor elements exposed	Columns and beams
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Sustainability
Architect	Voll Architects, NO
Engineer	Sweco, INT
Timber Engineer	Moelven, NO
General Contractor	HENT, NO
Timber Contractor	Moelven, NO - Woodcon, NO, SE, AT
Timber Supplier:	
Structural Elements	Moelven, NO - Stora Enso FI, SE
Floor Elements	Metsa Wood, FI - Stora Enso, FI, SE
Client	AB Invest, NO

SOURCE OF IMAGES

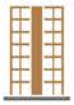
Moelven



Valle Wood

Year Completation	2019
Country	Norway
City	Oslo
Number of Storeys	7
Number Timber Storeys	7

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	6700
Total surface built (f²)	72119
Structural category	 Post-and-Beam all-timber
Podium	None
Core	CLT
Floor slabs	CLT-concrete
Program	Office
External Cladding	Wood
Indoor elements exposed	All the surfaces
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Sustainability
Architect	Lund-Slaatto Architetekter, NO
Engineer	Sweco, INT, Ing. Seim & Hultgreen, NO
Timber Engineer	Oslotre, NO
General Contractor	n/a
Timber Contractor	Beslagos, NO
Timber Supplier:	
Structural Elements	Moelven, NO
Floor Elements	KLH, AT
Client	NCC Property Development, NO

SOURCE OF IMAGES

NCC.com, Lund+Slaato Arkitekter

A.8 Spain

Project (name)	(image)	Storeys (number)	Timber Storeys (number)	Strucutral system (logo)	(category)	Core (material)	Floor Slabs (material)	Total Built Surface (m2)	Program (type)	Facade cladding (material)	Structural timber exposure (category)
Contralaminada		5	5		Panelised all-timber	CLT	CLT	940	Residential - Social Housing	Plaster	Ceiling
Hondarribia Visesa VPO		5	4		Panelised timber-concrete (podium)	CLT	CLT	9000	Residential - Social Housing	Other	Ceiling
ARV8		6	5		Panelised timber-concrete (podium)	CLT	CLT	1200	Residential	Metal	Ceiling
La Borda		7	6		Panelised timber-concrete (podium)	CLT	CLT	3000	Residential - Co-housing	Wood	Ceiling
15 Buenavista		5	4		Panelised timber-concrete (podium)	CLT	CLT	409	Residential	Wood	Walls

Contralaminada

Year Completation	2014
Country	Spain
City	Lleida
Number of Storeys	5
Number Timber Storeys	5

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	940
Total surface built (f²)	10118
Structural category	Panelised all-timber
Podium	None
Core	CLT
Floor slabs	CLT
Program	Residential - Social Housing
External Cladding	Plaster
Indoor elements exposed	Ceiling
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	n/a
Architect	Ramón Llobera i Serentill, ES
Engineer	Josep Cases i Roca, ES
Timber Engineer	Miguel Nevado, ES
General Contractor	Construccions Pallás, ES
Timber Contractor	Altermatéria, ES
Timber Supplier:	
Structural Elements	KLH, AT
Floor Elements	KLH, AT
Client	Arrendaments Sandiumenge, ES

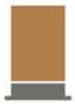
SOURCE OF IMAGES

Ramón Llobera i Serentill, KLH

Hondarribia Visesa VPO

Year Completation	2017
Country	Spain
City	Hondarribia
Number of Storeys	5
Number Timber Storeys	4

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	9000
Total surface built (f²)	96876
Structural category	 Panelised timber-concrete (podium)
Podium	Ground Floor
Core	CLT
Floor slabs	CLT
Program	Residential - Social Housing
External Cladding	Other
Indoor elements exposed	Ceiling
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Public
Motivations	Sustainability
Architect	TYM asociados, ES
Engineer	Egoin, ES
Timber Engineer	Egoin, ES
General Contractor	Visesa, ES
Timber Contractor	Egoin, ES
Timber Supplier:	
Structural Elements	Egoin, ES
Floor Elements	Egoin, ES
Client	Visesa, ES

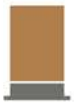
SOURCE OF IMAGES

Jon Guezala, Egoin

ARV8

Year Completation	2018
Country	Spain
City	Madrid
Number of Storeys	6
Number Timber Storeys	5

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	1200
Total surface built (f²)	12917
Structural category	 Panelised timber-concrete (podium)
Podium	Ground Floor
Core	CLT
Floor slabs	CLT
Program	Residential
External Cladding	Metal
Indoor elements exposed	Ceiling
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	n/a
Influence	Private
Motivations	n/a
Architect	Ábaton Arcquitectos, ES
Engineer	n/a
Timber Engineer	n/a
General Contractor	Madergia, ES
Timber Contractor	Madergia, ES
Timber Supplier:	
Structural Elements	Stora Enso, FI, SE
Floor Elements	Stora Enso, FI, SE
Client	n/a

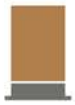
SOURCE OF IMAGES

Belén Imaz, Juan Baraja y Queima Films

La Borda

Year Completation	2018
Country	Spain
City	Barcellona
Number of Storeys	7
Number Timber Storeys	6

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	3000
Total surface built (f²)	32292
Structural category	 Panelised timber-concrete (podium)
Podium	Ground Floor
Core	CLT
Floor slabs	CLT
Program	Residential - Co-housing
External Cladding	Wood
Indoor elements exposed	Ceiling
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Sustainability
Architect	Lacol, ES
Engineer	Miguel Nevado, ES
Timber Engineer	Miguel Nevado, ES
General Contractor	MCM Projects, ES
Timber Contractor	Egoin, ES
Timber Supplier:	
Structural Elements	Egoin, ES
Floor Elements	Egoin, ES
Client	La borda cooperative, ES

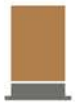
SOURCE OF IMAGES

Lluc Miralles, Lacol

15 Buenavista

Year Completation	2019
Country	Spain
City	Madrid
Number of Storeys	5
Number Timber Storeys	4

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	409
Total surface built (f²)	4401
Structural category	 Panelised timber-concrete (podium)
Podium	Ground Floor
Core	CLT
Floor slabs	CLT
Program	Residential
External Cladding	Wood
Indoor elements exposed	Walls
Building volume	Regular

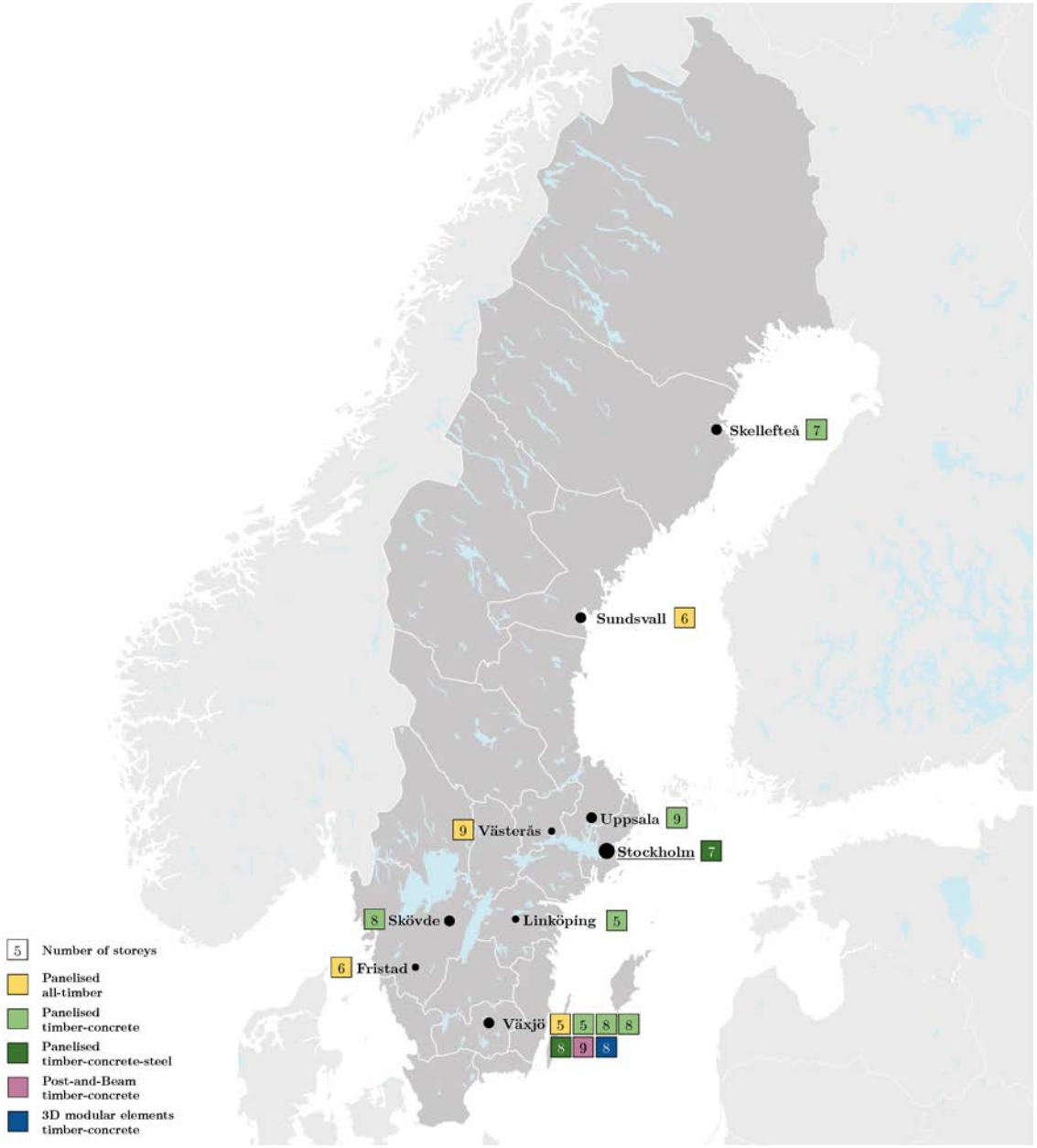
CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Sustainability
Architect	b720 Fermín Vázquez Arquitectos, ES
Engineer	Miguel Nevado, ES
Timber Engineer	Miguel Nevado, ES
General Contractor	Impacto Cero, ES
Timber Contractor	Altermatéria, ES
Timber Supplier:	
Structural Elements	KLH, AT
Floor Elements	KLH, AT
Client	Impacto Cero, ES

SOURCE OF IMAGES

Terabithia, Construible.es

A.9 Sweden


Skellefteå 7
Sundsvall 6
Uppsala 9
9 Västerås
Stockholm 7
8 Skövde
Linköping 5
6 Fristad
Växjö 5 5 8 8
8 9 8
5 Number of storeys
Panelised all-timber
Panelised timber-concrete
Panelised timber-concrete-steel
Post-and-Beam timber-concrete
3D modular elements timber-concrete

Project (name)	(image)	Storeys (number)	Timber Storeys (number)	Strucutral system (logo)	(category)	Core (material)	Floor Slabs (material)	Total Built Surface (m2)	Program (type)	Facade cladding (material)	Structural timber exposure (category)
Sundsvall I		6	6		Panelised all-timber	CLT	CLT-glulam	5040	Residential	Wood	None
Limnologen		8	7		Panelised timber-concrete-steel (podium-steel rods)	CLT	CLT-glulam	10700	Residential	Wood	None
Portvakten		8	7		Panelised timber-concrete (podium)	CLT	CLT-glulam	5444	Residential	Cement based	None
Älvsbacka Strand		7	6		Panelised timber-concrete (podium)	CLT	CLT	8820	Residential	Wood	None
Strandparken		7	6		Panelised timber-concrete-steel (podium-steel rods)	CLT	CLT	8120	Residential	Wood	None
Åsbovägen		6	6		Panelised all-timber	CLT	CLT	5960	Residential	Wood	Walls
Vallen		9	7		Post-and-Beam timber-concrete (podium-core)	Concrete	LVL	8016	Residential	Wood/Metal	None
Valla Berså		5	4		Panelised timber-concrete (podium)	CLT	CLT	3480	Residential	Wood	None
Docenten		8	6		3D Modular timber-concrete (podium-core)	Concrete	Box elements	9864	Student Housing	Metal	n/a
Ekologen		5	5		Panelised all-timber	CLT	CLT	5332	Residential	Wood	None
Frostaliden		8	6		Panelised timber-concrete (podium-core)	Concrete	CLT	4900	Residential	Wood	Walls
Botanikern		9	8		Panelised timber-concrete (podium)	CLT	CLT	13400	Residential	Wood	None
Kajstaden		9	9		Panelised all-timber	CLT	CLT	7500	Residential	Wood	None
Strandsnäckan		5	5		Panelised timber-concrete (core)	Concrete	CLT	8016	Residential	Wood	None
Trummens Strand		8	6		Panelised timber-concrete (podium)	CLT	CLT	22200	Residential	Wood	Ceiling

Sundsvall I

Year Completation	2005
Country	Sweden
City	Sundsvall
Number of Storeys	6
Number Timber Storeys	6

DESIGN DATA

Number of Buildings	3
Total surface built (m²)	5040
Total surface built (f²)	54251
Structural category	Panelised all-timber
Podium	None
Core	CLT
Floor slabs	CLT-Glulam
Program	Residential
External Cladding	Wood
Indoor elements exposed	None
Building volume	Pitched roof

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Public/Private
Motivations	Technical aspects
Architect	White Arkitekter, INT
Engineer	WSP Byggprojektering, SE
Timber Engineer	Martinsons, SE
General Contractor	NCC Construction Sverige, SE
Timber Contractor	Martinsons, SE
Timber Supplier:	
Structural Elements	Martinsons, SE
Floor Elements	Martinsons, SE
Client	NCC Construction Sverige - Luleå University of Technology, SE

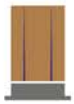
SOURCE OF IMAGES

Andreas Falk

Limnologen

Year Completation	2008
Country	Sweden
City	Växjö
Number of Storeys	8
Number Timber Storeys	7

DESIGN DATA

Number of Buildings	2
Total surface built (m²)	10700
Total surface built (f²)	115175
Structural category	 Panelised timber-concrete-steel (podium-steel rods)
Podium	Ground Floor
Core	CLT
Floor slabs	CLT-Glulam
Program	Residential
External Cladding	Wood
Indoor elements exposed	None
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Competition
Influence	Public/Private
Motivations	Sustainability
Architect	ArkitektBolaget, SE
Engineer	Tyréns, SE
Timber Engineer	Martinsons, SE
General Contractor	Midroc Projects, SE
Timber Contractor	Martinsons, SE
Timber Supplier:	
Structural Elements	Martinsons, SE
Floor Elements	Martinsons, SE
Client	Midroc Property development, SE

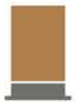
SOURCE OF IMAGES

Åke E:son Lindman, Ole Jais, informationsdienst-holz.de

Portvakten

Year Completation	2009
Country	Sweden
City	Växjö
Number of Storeys	8
Number Timber Storeys	7

DESIGN DATA

Number of Buildings	2
Total surface built (m²)	5444
Total surface built (f²)	58599
Structural category	 Panelised timber-concrete (podium)
Podium	Ground Floor
Core	CLT
Floor slabs	CLT-Glulam
Program	Residential
External Cladding	Cement based
Indoor elements exposed	None
Building volume	Pitched roof

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Public/Private
Motivations	Technical aspects
Architect	BSV Arkitekter & Ingenjörer, SE
Engineer	BSV Arkitekter \& Ingenjörer, SE
Timber Engineer	Martinsons, SE
General Contractor	NCC Construction Sverige - JSB, SE
Timber Contractor	Martinsons, SE
Timber Supplier:	
Structural Elements	Martinsons, SE
Floor Elements	Martinsons, SE
Client	Hyresbostäder, SE

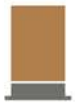
SOURCE OF IMAGES

Anders Bergön, GBJ Bygg

Älvsbacka Strand

Year Completation	2010
Country	Sweden
City	Skellefteå
Number of Storeys	7
Number Timber Storeys	6

DESIGN DATA

Number of Buildings	3
Total surface built (m²)	8820
Total surface built (f²)	94938
Structural category	 Panelised timber-concrete (podium)
Podium	Ground Floor
Core	CLT
Floor slabs	CLT
Program	Residential
External Cladding	Wood
Indoor elements exposed	None
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Competition
Influence	Public/Private
Motivations	Sustainability
Architect	White Arkitekter, INT
Engineer	Lindbäcks Bygg, SE
Timber Engineer	Martinsons, SE
General Contractor	Bygg i Trä, SE
Timber Contractor	Martinsons, SE
Timber Supplier:	
Structural Elements	Martinsons, SE
Floor Elements	Martinsons, SE
Client	Bygg i Trä, SE

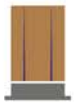
SOURCE OF IMAGES

Moelven, Enar Nordvik

Strandparken

Year Completation	2014
Country	Sweden
City	Stockholm
Number of Storeys	7
Number Timber Storeys	6

DESIGN DATA

Number of Buildings	2
Total surface built (m²)	8120
Total surface built (f²)	87404
Structural category	 Panelised timber-concrete-steel (podium-steel rods)
Podium	Ground Floor
Core	CLT
Floor slabs	CLT
Program	Residential
External Cladding	Wood
Indoor elements exposed	None
Building volume	Pitched roof

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Technical aspects
Architect	Wingårdhs Arkitekter, SE
Engineer	n/a
Timber Engineer	Martinsons, SE
General Contractor	Folkheim, SE
Timber Contractor	Martinsons, SE
Timber Supplier:	
Structural Elements	Martinsons, SE
Floor Elements	Martinsons, SE
Client	Folkheim, SE

SOURCE OF IMAGES

Tord-Rickard Siderstrim, Åke E:son Lindman europeanwood.org

Åsbovägen

Year Completation	2015
Country	Sweden
City	Fristad
Number of Storeys	6
Number Timber Storeys	6

DESIGN DATA

Number of Buildings	2
Total surface built (m²)	5960
Total surface built (f²)	64153
Structural category	Panelised all-timber
Podium	None
Core	CLT
Floor slabs	CLT
Program	Residential
External Cladding	Wood
Indoor elements exposed	Walls
Building volume	Pitched roof

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Public/Private
Motivations	Sustainability
Architect	Tengbom, SE
Engineer	n/a
Timber Engineer	n/a
General Contractor	Fristad Bygg, SE
Timber Contractor	Fristad Bygg, SE
Timber Supplier:	
Structural Elements	KLH, AT
Floor Elements	KLH, AT
Client	Fristadbostäder, SE

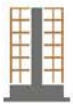
SOURCE OF IMAGES

Bert Leandersson, Fristad Bygg/KLH Sweden

Vallen

Year Completation	2015
Country	Sweden
City	Växjö
Number of Storeys	9
Number Timber Storeys	7

DESIGN DATA

Number of Buildings	3
Total surface built (m²)	8016
Total surface built (f²)	86284
Structural category	 Post-and-Beam timber-concrete (podium-core)
Podium	Up to first floor
Core	Concrete
Floor slabs	LVL
Program	Residential
External Cladding	Wood/Metal
Indoor elements exposed	None
Building volume	Pitched roof

CONTEXTUAL DATA

Type of Commission	Competition
Influence	Public
Motivations	Sustainability
Architect	ArkitektBolaget, SE
Engineer	Martin & Co, SE
Timber Engineer	Moelven, NO
General Contractor	GBJ bygg - Värends Entreprenad, SE
Timber Contractor	Holzapak, SE, US
Timber Supplier:	
Structural Elements	Moelven, NO
Floor Elements	Moelven, NO
Client	Växjöbostäder , SE

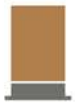
SOURCE OF IMAGES

Åke E:son Lindman, Moelven

Valla Berså

Year Completation	2016
Country	Sweden
City	Linköping
Number of Storeys	5
Number Timber Storeys	4

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	3480
Total surface built (f²)	37459
Structural category	 Panelised timber-concrete (podium)
Podium	Ground Floor
Core	CLT
Floor slabs	CLT
Program	Residential
External Cladding	Wood
Indoor elements exposed	None
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Sustainability
Architect	Winell & Jern Arkitekter, SE
Engineer	Gärderup Byggkonstruktion, SE
Timber Engineer	Martinsons, SE
General Contractor	Åhlin Ekroth Byggnads, SE
Timber Contractor	Martinsons, SE
Timber Supplier:	
Structural Elements	Martinsons, SE
Floor Elements	Martinsons, SE
Client	Lindstén fastigheter, SE

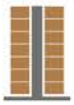
SOURCE OF IMAGES

Devis Bionaz, Martinsons

Docenten

Year Completation	2018
Country	Sweden
City	Växjö
Number of Storeys	8
Number Timber Storeys	6

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	9864
Total surface built (f²)	106176
Structural category	 3D Modular timber-concrete (podium-core)
Podium	Up to first floor
Core	Concrete
Floor slabs	Box Elements
Program	Student Housing
External Cladding	Metal
Indoor elements exposed	n/a
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	n/a
Influence	Public
Motivations	n/a
Architect	LBE Arkitekt, SE
Engineer	n/a
Timber Engineer	n/a
General Contractor	GBJ Bygg, SE
Timber Contractor	n/a
Timber Supplier:	
Structural Elements	n/a
Floor Elements	n/a
Client	Växjöbostäder, SE

SOURCE OF IMAGES

GBJ Bygg, Växjöbostäder

Ekologen

Year Completation	2018
Country	Sweden
City	Växjö
Number of Storeys	5
Number Timber Storeys	5

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	5332
Total surface built (f²)	57394
Structural category	Panelised all-timber
Podium	None
Core	CLT
Floor slabs	CLT
Program	Residential
External Cladding	Wood
Indoor elements exposed	None
Building volume	Pitched roof

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Sustainability
Architect	Arkitektlaget, NO
Engineer	n/a
Timber Engineer	n/a
General Contractor	Värends Entreprenad, SE
Timber Contractor	Martinsons - Bjerking, SE
Timber Supplier:	
Structural Elements	Martinsons, SE
Floor Elements	Martinsons, SE
Client	Midroc Property development, SE

SOURCE OF IMAGES

Anders Bergön, GBJ Bygg

Frostaliden

Year Completation	2018
Country	Sweden
City	Skövde
Number of Storeys	8
Number Timber Storeys	6

DESIGN DATA

Number of Buildings	2
Total surface built (m²)	4900
Total surface built (f²)	52744
Structural category	Panelised timber-concrete (podium-core)
Podium	Ground Floor
Core	Concrete
Floor slabs	CLT
Program	Residential
External Cladding	Wood
Indoor elements exposed	Walls
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Public/Private
Motivations	Sustainability
Architect	White Arkitekter, INT
Engineer	n/a
Timber Engineer	Fristad Bygg, SE
General Contractor	Fristad Bygg, SE
Timber Contractor	Fristad Bygg, SE
Timber Supplier:	
Structural Elements	KLH, AT
Floor Elements	KLH, AT
Client	Brunnen Bostad, SE

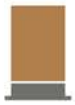
SOURCE OF IMAGES

Bert Leandersson, White Arkitekter

Botanikern

Year Completation	2019
Country	Sweden
City	Uppsala
Number of Storeys	9
Number Timber Storeys	8

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	13400
Total surface built (f²)	144238
Structural category	 Panelised timber-concrete (podium)
Podium	Ground Floor
Core	CLT
Floor slabs	CLT
Program	Residential
External Cladding	Wood
Indoor elements exposed	None
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Competition
Influence	Private
Motivations	Sustainability
Architect	Axeloth Arkitekter, SE
Engineer	Skonto Prefab, LV
Timber Engineer	Daniel Fagerberg, SE
General Contractor	Skonto Prefab, LV
Timber Contractor	Skonto Prefab, LV
Timber Supplier:	
Structural Elements	Cross Timber Systems (Skonto), LV
Floor Elements	Cross Timber Systems (Skonto), LV
Client	Genova Property Group, SE

SOURCE OF IMAGES

Mikael Olsson, Axeloth Arkitekter, Skonto Prefab

Kajstaden

Year Completation	2019
Country	Sweden
City	Västerås
Number of Storeys	9
Number Timber Storeys	9

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	7500
Total surface built (f²)	80730
Structural category	Panelised all-timber
Podium	None
Core	CLT
Floor slabs	CLT
Program	Residential
External Cladding	Wood
Indoor elements exposed	None
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Sustainability
Architect	C.F. Moller Architects, INT
Engineer	Bjerking, SE
Timber Engineer	Martinsons, SE
General Contractor	Consto, SE
Timber Contractor	Martinsons, SE
Timber Supplier:	
Structural Elements	Martinsons, SE
Floor Elements	Martinsons, SE
Client	Slättö Förvaltning, SE

SOURCE OF IMAGES

Nikolaj Jakobsen

Strandsnäckan

Year Completation	2019
Country	Sweden
City	Växjö
Number of Storeys	5
Number Timber Storeys	5

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	8016
Total surface built (f²)	86284
Structural category	Panelised timber-concrete (core)
Podium	None
Core	Concrete
Floor slabs	CLT
Program	Residential
External Cladding	Wood
Indoor elements exposed	None
Building volume	Different heights

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Sustainability
Architect	ArkitektBolaget, SE
Engineer	Projektbyggare, SE
Timber Engineer	Binderholz, AT
General Contractor	GBJ Bygg, SE
Timber Contractor	Binderholz, AT
Timber Supplier:	
Structural Elements	Binderholz, AT
Floor Elements	Binderholz, AT
Client	BATTEN fastigheter, SE

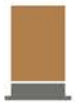
SOURCE OF IMAGES

Åke E:son Lindman

Trummens Strand

Year Completation	2019
Country	Sweden
City	Växjö
Number of Storeys	8
Number Timber Storeys	6

DESIGN DATA

Number of Buildings	4
Total surface built (m²)	22200
Total surface built (f²)	238961
Structural category	 Panelised timber-concrete (podium)
Podium	Up to 1 floor
Core	CLT
Floor slabs	CLT
Program	Residential
External Cladding	Wood
Indoor elements exposed	Ceiling
Building volume	Pitched roof

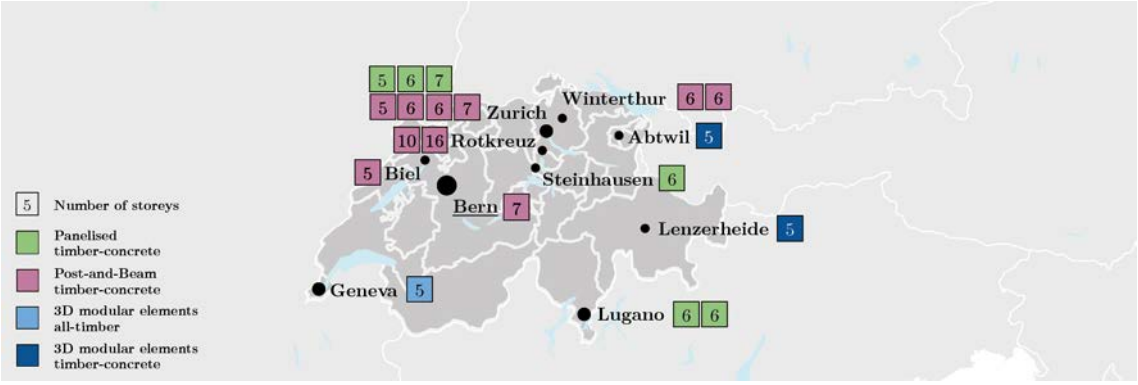
CONTEXTUAL DATA

Type of Commission	Direct
Influence	Public/Private
Motivations	Sustainability
Architect	Fojab Arkitekter, SE
Engineer	Projektbyggaren, SE
Timber Engineer	Woodcon, NO, SE, AT
General Contractor	GBJ Bygg, SE
Timber Contractor	Woodcon, NO, SE, AT
Timber Supplier:	
Structural Elements	Stora Enso, FI, SE
Floor Elements	Stora Enso, FI, SE
Client	GBJ Bygg, SE

SOURCE OF IMAGES

Anders Bergön, GBJ Bygg

A.10 Switzerland



Project (name)	(image)	Storeys (number)	Timber Storeys (number)	Strucutral system (logo)	(category)	Core (material)	Floor Slabs (material)	Total Built Surface (m2)	Program (type)	Facade cladding (material)	Structural timber exposure (category)
Holzhausen		6	6		Panelised timber-concrete (core)	Concrete	Box elements	2090	Residential	Wood	None
Casa Montarina		6	5		Panelised timber-concrete (podium)	None	Box elements	950	Residential	Other	Ceiling
Badenerstrasse		7	6		Panelised timber-concrete (podium-core)	Concrete	Box elements	13876	Residential	Cement based	None
Wohnhaus Habsburgstrasse		5	5		Post-and-Beam timber-concrete (core)	Concrete	Box elements	2115	Residential	Plaster	None
Residenza Sirio		6	6		Panelised timber-concrete (core)	Concrete	CLT	6069	Residential	Plaster	None
Mühlebachstrasse		6	6		Post-and-Beam timber-concrete (core)	Concrete	DLT-concrete	5520	Mixed Use (residential-office)	Other	None
Giesserei		6	5		Post-and-Beam timber-concrete (podium-core)	Concrete	DLT	29265	Residential - Social Housing	Wood	None
SZU-Betrisbgebaude		6	4		Post-and-Beam timber-concrete (podium-core)	Concrete	Box elements	5127	Residential	Plaster	None
Tamedia Office		7	7		Post-and-Beam timber-concrete (core)	Concrete	Glulam	8905	Office	Curtain wall	All the surfaces
Hotel Saentispark		5	4		3D Modular timber-concrete (podium-core)	Concrete	Glulam-concrete	9725	Hotel	Wood	All the surfaces
Mehr als Wohnen Haus J		5	4		Post-and-Beam timber-concrete (podium-core)	Concrete	DLT	4021	Residential - Social Housing	Other	All the surfaces
Siloah		7	6		Post-and-Beam timber-concrete (podium-core)	Concrete	Box elements	4500	Hospital	Metal	None
Zollfreilager Housing		6	6		Panelised timber-concrete (core)	Concrete	DLT	20050	Residential	Wood	None
Hotel Revier		5	4		3D Modular timber-concrete (podium-core)	Concrete	CLT	4100	Hotel	Wood	All the surfaces
sue&til		6	5		Post-and-Beam timber-concrete (podium-core)	Concrete	Box elements	53000	Residential	Metal	All the surfaces
Suurstoffi S22		10	9		Post-and-Beam timber-concrete (podium-core)	Concrete	Glulam-and LVL-concrete	17900	Office	Metal	All the surfaces
Arbo		16	16		Post-and-Beam timber-concrete (core)	Concrete	LVL-concrete	13513	Office	Curtain wall	All the surfaces
Asylunterkunft Rigot		5	5		3D Modular element all-timber	None	CLT	7070	Residential -Asylumseekers	Wood	All the surfaces
Omega Headquarters		5	4		Post-and-Beam timber-concrete (podium-core)	Concrete	Glulam-concrete	19000	Office	Curtain wall	Columns and beams

Holzhausen

Year Completation	2006
Country	Switzerland
City	Steinhausen
Number of Storeys	6
Number Timber Storeys	6

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	2090
Total surface built (f²)	22497
Structural category	Panelised timber-concrete (core)
Podium	None
Core	Concrete
Floor slabs	Box Elements
Program	Residential
External Cladding	Wood
Indoor elements exposed	None
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Sustainability
Architect	Scheitlin Syfrig Architekten, CH
Engineer	Makiol-Wiederkehr, CH
Timber Engineer	Renngli, CH
General Contractor	Renngli, CH
Timber Contractor	Renngli, CH
Timber Supplier:	
Structural Elements	Renngli, CH
Floor Elements	Renngli, CH
Client	Dölf und Maria Gubser Furrer, CH

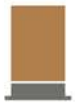
SOURCE OF IMAGES

Renggli, iningenieursteckt.ch

Casa Montarina

Year Completation	2007
Country	Switzerland
City	Lugano
Number of Storeys	6
Number Timber Storeys	5

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	950
Total surface built (f²)	10226
Structural category	 Panelised timber-concrete (podium)
Podium	Ground Floor
Core	None
Floor slabs	Box Elements
Program	Residential
External Cladding	Other
Indoor elements exposed	Ceiling
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Sustainability
Architect	Lorenzo Felder Archietetto, CH
Engineer	Borlini& Zanini, CH
Timber Engineer	Borlini& Zanini, CH
General Contractor	Lepori - Laube, CH
Timber Contractor	Gandelli Group, IT, CH
Timber Supplier:	
Structural Elements	Stora Enso, FI, SE
Floor Elements	Stora Enso, FI, SE
Client	Mimi Lepori Bonetti, Lorenzo Felder, CH

SOURCE OF IMAGES

Lorenzo Felder architettura

Badenerstrasse

Year Completation	2010
Country	Switzerland
City	Zurich
Number of Storeys	7
Number Timber Storeys	6

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	13876
Total surface built (f²)	149361
Structural category	Panelised timber-concrete (podium-core)
Podium	Ground Floor
Core	Concrete
Floor slabs	Box Elements
Program	Residential
External Cladding	Cement based
Indoor elements exposed	None
Building volume	Different heights

CONTEXTUAL DATA

Type of Commission	Competition
Influence	Private
Motivations	Technical aspects
Architect	pool Architekten, CH
Engineer	Henauer - Gugler, CH
Timber Engineer	SJB Kempter Fitze, CH
General Contractor	Caretta Weidmann, CH
Timber Contractor	Zimmereigenossenschaft Zürich, CH
Timber Supplier:	
Structural Elements	Zimmereigenossenschaft Zürich, CH
Floor Elements	Zimmereigenossenschaft Zürich, CH
Client	Baugenossenschaft Zurlinden, CH

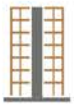
SOURCE OF IMAGES

Giuseppe Micciché, pro Holz

Wohnhaus Habsburgstrasse

Year Completation	2011
Country	Switzerland
City	Zurich
Number of Storeys	5
Number Timber Storeys	5

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	2115
Total surface built (f²)	22766
Structural category	 Post-and-Beam timber-concrete (core)
Podium	None
Core	Concrete
Floor slabs	Box Elements
Program	Residential
External Cladding	Plaster
Indoor elements exposed	None
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Sustainability
Architect	Hauenstein LaRoche Schedler Architekten, CH
Engineer	Urech Bärtschi Maurer, CH
Timber Engineer	Timbatec, CH, AT
General Contractor	Hector Egger Holzbau, CH
Timber Contractor	Hector Egger Holzbau, CH
Timber Supplier:	
Structural Elements	Hector Egger Holzbau, CH
Floor Elements	Hector Egger Holzbau, CH
Client	Einfache Gesellschaft Osterwalder-Dahm, CH

SOURCE OF IMAGES

Hannes Henz, Hauenstein LaRoche Schedler Architekten

Residenza Sirio

Year Completation	2012
Country	Switzerland
City	Lugano
Number of Storeys	6
Number Timber Storeys	6

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	6069
Total surface built (f²)	65327
Structural category	Panelised timber-concrete (core)
Podium	None
Core	Concrete
Floor slabs	CLT
Program	Residential
External Cladding	Plaster
Indoor elements exposed	None
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Sustainability
Architect	Ecoedil, CH
Engineer	Geom. Viviani, CH
Timber Engineer	Borlini& Zanini, CH
General Contractor	Service Legno, IT
Timber Contractor	Service Legno, IT
Timber Supplier:	
Structural Elements	Stora Enso, FI, SE
Floor Elements	Stora Enso, FI, SE
Client	A.Serta and J.Terzic, CH

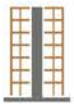
SOURCE OF IMAGES

Maurizio Marzi Architetto

Mühlebachstrasse

Year Completation	2012
Country	Switzerland
City	Zurich
Number of Storeys	6
Number Timber Storeys	6

DESIGN DATA

Number of Buildings	2
Total surface built (m²)	5520
Total surface built (f²)	59417
Structural category	 Post-and-Beam timber-concrete (core)
Podium	None
Core	Concrete
Floor slabs	DLT- Concrete
Program	Mixed Use (residential-office)
External Cladding	Other
Indoor elements exposed	None
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	n/a
Architect	Kämpfen für architektur, CH
Engineer	De Vries Engineering, CH
Timber Engineer	Makiol-Wiederkehr, CH
General Contractor	Hector Egger Holzbau - 1a hunkeler, CH
Timber Contractor	Hector Egger Holzbau - 1a hunkeler, CH
Timber Supplier:	
Structural Elements	Hector Egger Holzbau - 1a hunkeler, CH
Floor Elements	Hector Egger Holzbau - 1a hunkeler, CH
Client	Monika und Muriel Kämpfen, CH"

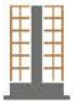
SOURCE OF IMAGES

Kämpfen für architektur

Giesserei

Year Completation	2013
Country	Switzerland
City	Winterthur
Number of Storeys	6
Number Timber Storeys	5

DESIGN DATA

Number of Buildings	2
Total surface built (m²)	29265
Total surface built (f²)	315008
Structural category	 Post-and-Beam timber-concrete (podium-core)
Podium	Ground Floor
Core	Concrete
Floor slabs	DLT
Program	Residential - Social Housing
External Cladding	Wood
Indoor elements exposed	None
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Competition
Influence	Public/Private
Motivations	Sustainability
Architect	Galli Rudolf Architekten, CH
Engineer	Indermühle Bauingenieure, CH
Timber Engineer	Indermühle Bauingenieure, CH
General Contractor	Implenia Schweiz, CH
Timber Contractor	Knecht, Implenia Bau - Brunner Erben, CH
Timber Supplier:	
Structural Elements	Knecht, Implenia Bau - Brunner Erben, CH
Floor Elements	Knecht, Implenia Bau - Brunner Erben, CH
Client	Gesewo - Allianz Suisse, CH

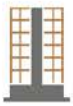
SOURCE OF IMAGES

Hannes Henz, Implenia Schweiz

SZU-Betrisbgebaude

Year Completation	2013
Country	Switzerland
City	Zurich
Number of Storeys	6
Number Timber Storeys	4

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	5127
Total surface built (f²)	55187
Structural category	 Post-and-Beam timber-concrete (podium-core)
Podium	Addition existing building
Core	Concrete
Floor slabs	Box Elements
Program	Residential
External Cladding	Plaster
Indoor elements exposed	None
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Competition
Influence	Private
Motivations	Technical aspects
Architect	Burkhalter Sumi Architekten, CH
Engineer	Dr.Lüchinger - Meyer, CH
Timber Engineer	Hector Egger Holzbau, CH
General Contractor	Unirenova, CH
Timber Contractor	Hector Egger Holzbau, CH
Timber Supplier:	
Structural Elements	Hector Egger Holzbau, CH
Floor Elements	Hector Egger Holzbau, CH
Client	SZU, CH

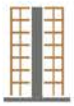
SOURCE OF IMAGES

Georg Aerni, Heinz Unger

Tamedia Office

Year Completation	2013
Country	Switzerland
City	Zurich
Number of Storeys	7
Number Timber Storeys	7

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	8905
Total surface built (f²)	95853
Structural category	 Post-and-Beam timber-concrete (core)
Podium	None
Core	Concrete
Floor slabs	Glulam
Program	Office
External Cladding	Curtain wall
Indoor elements exposed	All the surfaces
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Technical aspects
Architect	Shigeru Ban Architects, JP
Engineer	Creation Holz, CH
Timber Engineer	Creation Holz, CH
General Contractor	HRS Real Estate, CH
Timber Contractor	Blumer-Lehmann, CH
Timber Supplier:	
Structural Elements	Blumer-Lehmann, CH
Floor Elements	Blumer-Lehmann, CH
Client	Tamedia, CH

SOURCE OF IMAGES

Didier Boy de la Tour, Shigeru Ban Architects

Hotel Saentispark

Year Completation	2014
Country	Switzerland
City	Abtwil
Number of Storeys	5
Number Timber Storeys	4

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	9725
Total surface built (f²)	104680
Structural category	3D Modular timber-concrete (podium-core)
Podium	Ground Floor
Core	Concrete
Floor slabs	Glulam-concrete
Program	Hotel
External Cladding	Wood
Indoor elements exposed	All the surfaces
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Competition
Influence	Private
Motivations	Building erection speed
Architect	Carlos Martinez Architekten, CH
Engineer	Naenny - Partner, CH
Timber Engineer	SJB Kempter Fitze, CH
General Contractor	HRS Real Estate - HRS Renovationen, CH
Timber Contractor	Blumer-Lehmann, CH
Timber Supplier:	
Structural Elements	Blumer-Lehmann, CH
Floor Elements	Blumer-Lehmann, CH
Client	HRS Real Estate, CH

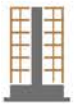
SOURCE OF IMAGES

Hannes Thalmann, HRS Real Estate

Mehr als Wohnen Haus I+J

Year Completation	2015
Country	Switzerland
City	Zurich
Number of Storeys	5
Number Timber Storeys	4

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	4021
Total surface built (f²)	43282
Structural category	 Post-and-Beam timber-concrete (podium-core)
Podium	Ground Floor
Core	Concrete
Floor slabs	DLT
Program	Residential - Social Housing
External Cladding	Other
Indoor elements exposed	All the surfaces
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Competition
Influence	Public
Motivations	Sustainability
Architect	pool Architekten - Futurafrosch, CH
Engineer	Edy Toscano - Ernst Basler-Partner, CH
Timber Engineer	Blumer-Lehmann, CH
General Contractor	Sohm, CH
Timber Contractor	Sohm, CH
Timber Supplier:	
Structural Elements	Sohm, CH
Floor Elements	Sohm, CH
Client	Baugenoschennschaft Mehr als Wohnen, CH

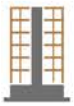
SOURCE OF IMAGES

Blumer-Lehmann, pool Architekten

Siloah

Year Completation	2015
Country	Switzerland
City	Bern
Number of Storeys	7
Number Timber Storeys	6

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	4500
Total surface built (f²)	48438
Structural category	 Post-and-Beam timber-concrete (podium-core)
Podium	Ground Floor
Core	Concrete
Floor slabs	Box Elements
Program	Hospital
External Cladding	Metal
Indoor elements exposed	None
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Technical aspects
Architect	Andreas Garraux Architekt, CH
Engineer	Emch - Berger - Makiol Wiederkehr - Grünig & Partner, CH
Timber Engineer	Emch - Berger - Makiol Wiederkehr - Grünig \& Partner, CH
General Contractor	Renngli, CH
Timber Contractor	Renngli, CH
Timber Supplier:	
Structural Elements	Renngli, CH
Floor Elements	Renngli, CH
Client	Stiftung Siloah, CH

SOURCE OF IMAGES

Renngli

Zollfreilager Housing

Year Completation	2016
Country	Switzerland
City	Zurich
Number of Storeys	6
Number Timber Storeys	6

DESIGN DATA

Number of Buildings	3
Total surface built (m²)	20050
Total surface built (f²)	215818
Structural category	Panelised timber-concrete (core)
Podium	None
Core	Concrete
Floor slabs	DLT
Program	Residential
External Cladding	Wood
Indoor elements exposed	None
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Competition
Influence	Private
Motivations	Technical aspects
Architect	Rolf Mühlethaler Architekt, CH
Engineer	Adamina Zeerleder Partner - MPAG Marchand-Partner, CH
Timber Engineer	Indermühle Bauingenieure, CH
General Contractor	Allreal Generalunternehmung, CH
Timber Contractor	Renngli, CH
Timber Supplier:	
Structural Elements	Renngli, CH
Floor Elements	Renngli, CH
Client	Zürcher Freilager, CH

SOURCE OF IMAGES

Renngli

Hotel Revier

Year Completation	2017
Country	Switzerland
City	Lenzerheide
Number of Storeys	5
Number Timber Storeys	4

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	4100
Total surface built (f²)	44132
Structural category	3D Modular timber-concrete (podium-core)
Podium	Ground Floor
Core	Concrete
Floor slabs	CLT
Program	Hotel
External Cladding	Wood
Indoor elements exposed	All the surfaces
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Competition
Influence	Private
Motivations	Technical aspects
Architect	Carlos Martinez Architekten, CH
Engineer	Plan 4, CH
Timber Engineer	Josef Kolb, CH
General Contractor	Baukla generalunternehmung, CH
Timber Contractor	Kaufmann Bausysteme, AT
Timber Supplier:	
Structural Elements	Binderholz, AT
Floor Elements	Binderholz, AT
Client	Fortimo Invest, CH

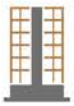
SOURCE OF IMAGES

Kaufmann Bausysteme, Nik Sarbach

sue & til

Year Completation	2018
Country	Switzerland
City	Winterthur
Number of Storeys	6
Number Timber Storeys	5

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	53000
Total surface built (f²)	570492
Structural category	 Post-and-Beam timber-concrete (podium-core)
Podium	Ground Floor
Core	Concrete
Floor slabs	Box Elements
Program	Residential
External Cladding	Metal
Indoor elements exposed	All the surfaces
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Competition
Influence	Private
Motivations	Sustainability
Architect	Weberbrunner Architekten - Soppelsa Architekten, CH
Engineer	Dr. J.Grob & Partner, CH
Timber Engineer	Timbatec, CH, AT
General Contractor	Implenia Schweiz, CH
Timber Contractor	Implenia Schweiz, CH
Timber Supplier:	
Structural Elements	Implenia Schweiz, CH
Floor Elements	Implenia Schweiz, CH
Client	Allianz Suisse, CH

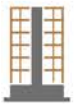
SOURCE OF IMAGES

Timbatec

Suurstoffi S22

Year Completation	2018
Country	Switzerland
City	Rotkreuz
Number of Storeys	10
Number Timber Storeys	9

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	17900
Total surface built (f²)	192676
Structural category	 Post-and-Beam timber-concrete (podium-core)
Podium	Ground Floor
Core	Concrete
Floor slabs	Glulam-concrete and LVL-Concrete
Program	Office
External Cladding	Metal
Indoor elements exposed	Ceiling, Columns and beams
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Competition
Influence	Private
Motivations	Technical aspects
Architect	Burkard Meyer Architekten, CH
Engineer	MWV Ingenieure, CH
Timber Engineer	Erne Holzbau, CH
General Contractor	Erne Holzbau, CH
Timber Contractor	Erne Holzbau, CH
Timber Supplier:	
Structural Elements	Hess Timber, DE
Floor Elements	Pollmeier, DE
Client	Zug Estates, CH

SOURCE OF IMAGES

Roger Frei, Erne AG, Markus Bertschi

Arbo Suurstoffi BF1

Year Completation	2019
Country	Switzerland
City	Rotkreuz
Number of Storeys	16
Number Timber Storeys	16

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	13513
Total surface built (f²)	145454
Structural category	Post-and-Beam timber-concrete (podium)
Podium	None
Core	Concrete
Floor slabs	LVL-Concrete
Program	Office
External Cladding	Curtain wall
Indoor elements exposed	Ceiling, Columns and beams
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Competition
Influence	Private
Motivations	Technical aspects
Architect	Büro Konstrukt - Manetsch Meyer, CH
Engineer	Dr.Luchniger-Meyer, CH
Timber Engineer	Pirmin Jung Ingenieure, CH - TiComTec, DE
General Contractor	Archobau, CH
Timber Contractor	Erne Holzbau, CH
Timber Supplier:	
Structural Elements	Pollmeier, DE
Floor Elements	Pollmeier, DE
Client	Zug Estates, CH

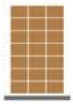
SOURCE OF IMAGES

Zug Estates, Kuster Frey, Erne AG

Asylunterkunft Rigot

Year Completation	2019
Country	Switzerland
City	Geneva
Number of Storeys	5
Number Timber Storeys	5

DESIGN DATA

Number of Buildings	2
Total surface built (m²)	7070
Total surface built (f²)	76101
Structural category	 3D Modular element all-timber
Podium	None
Core	None
Floor slabs	CLT
Program	Residential - Asylumseekers
External Cladding	Wood
Indoor elements exposed	All the surfaces
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Public
Motivations	Building erection speed
Architect	Acau Architecture, CH
Engineer	T-ingéniére-Thomas Jundt, CH
Timber Engineer	Charpente Concept, JDP-Ducret, CH
General Contractor	Enterprise Générale - JPF Construction, CH
Timber Contractor	JDF-Ducret SA - Dasta Charpente Bois SA - Casai SA, CH
Timber Supplier:	
Structural Elements and Floor Elements	Desponds - Bulle - Zahnd - Burgat - A-C Corbat, CH
Client	Hospice général - Service immobilier - Les Acacias, CH

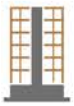
SOURCE OF IMAGES

Acau architecture

Omega Factory

Year Completation	2019
Country	Switzerland
City	Biel
Number of Storeys	5
Number Timber Storeys	4

DESIGN DATA

Number of Buildings	2
Total surface built (m²)	19000
Total surface built (f²)	204516
Structural category	 Post-and-Beam timber-concrete (podium-core)
Podium	Ground Floor
Core	Concrete
Floor slabs	Glulam-concrete
Program	Office
External Cladding	Curtain wall
Indoor elements exposed	Columns and beams
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Competition
Influence	Private
Motivations	Technical aspects
Architect	Shigeru Ban Architects, JP
Engineer	SJB Kempter Fitze, CH
Timber Engineer	SJB Kempter Fitze - Design-to-Production, CH
General Contractor	Blumer-Lehmann, CH
Timber Contractor	Blumer-Lehmann, CH
Timber Supplier:	
Structural Elements	Hess Timber, DE
Floor Elements	Blumer-Lehmann - Lehmann Holzwerk, CH
Client	Hayek family, CH

SOURCE OF IMAGES

Paula Pintos

A.11 United Kingdom

Project (name)	(image)	Storeys (number)	Timber Storeys (number)	Structural system (logo)	(category)	Core (material)	Floor Slabs (material)	Total Built Surface (m2)	Program (type)	Facade cladding (material)	Structural timber exposure (category)
Fairmule House		5	5		Panelised all-timber	CLT	CLT	2700	Residential	Bricks	Ceiling
Stadthaus		9	8		Panelised timber-concrete (podium)	CLT	CLT	3100	Residential	Metal	None
Birdport House		8	8		Panelised all-timber	CLT	CLT	5500	Residential	Bricks	None
Whitmore Road		6	5		Panelised timber-concrete (podium)	CLT	CLT	1022	Mixed Use (residential-office)	Wood	Ceiling
Kingsgate House		7	5		Panelised timber-concrete (podium)	CLT	CLT	4200	Residential - Social Housing	Other	None
UEA Crome Court		7	7		Panelised all-timber	CLT	CLT	9300	Student Housing	Metal	None
Cobalt Place		6	6		Panelised all-timber	CLT	CLT	10900	Residential	Bricks	Ceiling
Curtain Place		6	6		Panelised timber-steel (podium)	CLT	CLT	2250	Mixed Use (residential-office)	Bricks	Ceiling
Trafalgar Place		5	3		Panelised timber-concrete (podium)	CLT	CLT	1800	Residential	Bricks	None
Wenlock Road 17-21		10	9		Panelised timber-concrete-steel (podium-core-steel frame)	Concrete	CLT	6750	Residential	Wood	None
106 Lewes Road		5	4		Panelised timber-concrete (podium)	CLT	CLT	1650	Student Housing	Bricks	None
Nordic Lofts		5	5		Panelised all-timber	CLT	CLT	520	Residential	Bricks	All the surfaces
UEA Blackdale		6	6		Panelised all-timber	CLT	CLT	16470	Student Housing	Metal	None
Woodberry Down		5	5		Panelised all-timber	CLT	CLT	1575	Residential	Bricks	Ceiling
Bacton Low Rise		5	5		Panelised all-timber	CLT	CLT	7634	Residential	Bricks	None
Dalston Lane		11	10		Panelised timber-concrete (podium)	CLT	CLT	16000	Residential	Bricks	None
Highpoint Terrace		8	8		Panelised all-timber	CLT	CLT	12650	Residential - Social Housing	Metal	None
Hands Building		5	4		Panelised timber-concrete (podium)	CLT	CLT	2700	Student Housing	Other	Walls
Press House		9	8		Panelised timber-concrete (podium)	CLT	CLT	3750	Residential	Bricks	None
Boiler House		7	6		Panelised timber-concrete (podium)	CLT	CLT	4050	Residential	Metal	None
Ellerslie Road		7	7		Panelised all-timber	CLT	CLT	4200	Residential - Social Housing	Bricks	None
Pitfield Street		6	5		Panelised timber-concrete (podium)	CLT	CLT	3750	Mixed Use (residential-other)	Bricks	None
Green House		7	7		Panelised all-timber	CLT	CLT	4645	Office	Plaster	None

Fairmule House

Year Completation	2006
Country	U.K.
City	London
Number of Storeys	5
Number Timber Storeys	5

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	2700
Total surface built (f²)	29063
Structural category	Panelised all-timber
Podium	None
Core	CLT
Floor slabs	CLT
Program	Residential
External Cladding	Bricks
Indoor elements exposed	Ceiling
Building volume	Different heights

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Sustainability
Architect	Quay 2c, GB
Engineer	Anders Associates, GB
Timber Engineer	Eurban, GB
General Contractor	L I Construction, GB
Timber Contractor	Eurban, GB
Timber Supplier:	
Structural Elements	KLH, AT
Floor Elements	KLH, AT
Client	Lint Group, GB

SOURCE OF IMAGES

Quay 2c Architects, Lint Group

Stadthaus

Year Completation	2008
Country	U.K.
City	London
Number of Storeys	9
Number Timber Storeys	8

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	3100
Total surface built (f²)	33368
Structural category	Panelised timber-concrete (podium)
Podium	Ground Floor
Core	CLT
Floor slabs	CLT
Program	Residential
External Cladding	Metal
Indoor elements exposed	None
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Sustainability
Architect	Waugh Thistleton Architects, GB
Engineer	Techniker, GB
Timber Engineer	Techniker, GB - KLH, AT
General Contractor	Telford Homes, GB
Timber Contractor	KLH, AT
Timber Supplier:	
Structural Elements	KLH, AT
Floor Elements	KLH, AT
Client	Telford Homes, GB

SOURCE OF IMAGES

KLH, Waugh Thistleton Architects

Bridport House

Year Completation	2011
Country	U.K.
City	London
Number of Storeys	8
Number Timber Storeys	8

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	5500
Total surface built (f²)	59202
Structural category	Panelised all-timber
Podium	None
Core	CLT
Floor slabs	CLT
Program	Residential
External Cladding	Bricks
Indoor elements exposed	None
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Competition
Influence	Public
Motivations	Technical aspects
Architect	Karakusevic Carson Architects, GB
Engineer	Peter Bret Associates, GB
Timber Engineer	Eurban, GB
General Contractor	Willmott Dixon, GB
Timber Contractor	Eurban, GB
Timber Supplier:	
Structural Elements	Stora Enso, FI, SE
Floor Elements	Stora Enso, FI, SE
Client	London Borough of Hackney, GB

SOURCE OF IMAGES

proHolz, Eurban

Whitmore Road

Year Completation	2012
Country	U.K.
City	London
Number of Storeys	6
Number Timber Storeys	5

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	1022
Total surface built (f²)	11000
Structural category	Panelised timber-concrete (podium)
Podium	Ground Floor
Core	CLT
Floor slabs	CLT
Program	Mixed Use (residential-office)
External Cladding	Wood
Indoor elements exposed	Ceiling
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Sustainability
Architect	Waugh Thistleton Architects, GB
Engineer	Akera Engineers, GB
Timber Engineer	KLH, AT
General Contractor	Jerram Falkus Construction, GB
Timber Contractor	KLH, AT
Timber Supplier:	
Structural Elements	KLH, AT
Floor Elements	KLH, AT
Client	Withheld, GB

SOURCE OF IMAGES

Waugh Thistleton Architects

Kingsgate House

Year Completation	2014
Country	U.K.
City	London
Number of Storeys	7
Number Timber Storeys	5

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	4200
Total surface built (f²)	45209
Structural category	Panelised timber-concrete (podium)
Podium	Up to 1 floor
Core	CLT
Floor slabs	CLT
Program	Residential - Social Housing
External Cladding	Other
Indoor elements exposed	None
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Sustainability
Architect	Horden Cherry Lee Architects, GB
Engineer	Price & Myers, GB
Timber Engineer	KLH, AT
General Contractor	Willmott Dixon, GB
Timber Contractor	KLH, AT
Timber Supplier:	
Structural Elements	KLH, AT
Floor Elements	KLH, AT
Client	Catalyst Housing, GB

SOURCE OF IMAGES

proHolz, Price & Myers, KLH

UEA Crome Court

Year Completation	2014
Country	U.K.
City	Norwich
Number of Storeys	7
Number Timber Storeys	7

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	9300
Total surface built (f²)	100105
Structural category	Panelised all-timber
Podium	None
Core	CLT
Floor slabs	CLT
Program	Student Housing
External Cladding	Metal
Indoor elements exposed	None
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Public
Motivations	Technical aspects
Architect	LSI Architects, GB
Engineer	Eurban, GB
Timber Engineer	Eurban, GB
General Contractor	Keir Construction, GB
Timber Contractor	Eurban, GB
Timber Supplier:	
Structural Elements	Stora Enso, FI, SE
Floor Elements	Stora Enso, FI, SE
Client	University East Anglia, GB

SOURCE OF IMAGES

Ramboll, KLH

Cobalt Place

Year Completation	2015
Country	U.K.
City	London
Number of Storeys	6
Number Timber Storeys	6

DESIGN DATA

Number of Buildings	2
Total surface built (m²)	10900
Total surface built (f²)	117328
Structural category	Panelised all-timber
Podium	None
Core	CLT
Floor slabs	CLT
Program	Residential
External Cladding	Bricks
Indoor elements exposed	Ceiling
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Technical aspects
Architect	AHMM Architects, GB
Engineer	Walsh Associates, GB
Timber Engineer	Eurban, GB
General Contractor	Lendlease, INT
Timber Contractor	Eurban, GB
Timber Supplier:	
Structural Elements	Stora Enso, FI, SE
Floor Elements	Stora Enso, FI, SE
Client	Lendlease, INT

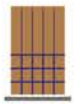
SOURCE OF IMAGES

Trada, Chartbury, Building.co

Curtain Place

Year Completation	2015
Country	U.K.
City	London
Number of Storeys	6
Number Timber Storeys	6

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	2250
Total surface built (f²)	24219
Structural category	 Panelised timber-steel (podium)
Podium	None
Core	CLT
Floor slabs	CLT
Program	Mixed Use (residential-office)
External Cladding	Bricks
Indoor elements exposed	Ceiling
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	n/a
Influence	Private
Motivations	n/a
Architect	Waugh Thistleton Architects, GB
Engineer	Richard Jackson Engineering, GB
Timber Engineer	B & K Structures - Engenuiti, GB
General Contractor	Gold Section Homes, GB
Timber Contractor	B & K Structures, GB
Timber Supplier:	
Structural Elements	Binderholz, AT
Floor Elements	Binderholz, AT
Client	Gold Section Homes, GB

SOURCE OF IMAGES

Waugh Thistleton Architects

Trafalgar Place

Year Completation	2015
Country	U.K.
City	London
Number of Storeys	5
Number Timber Storeys	3

DESIGN DATA

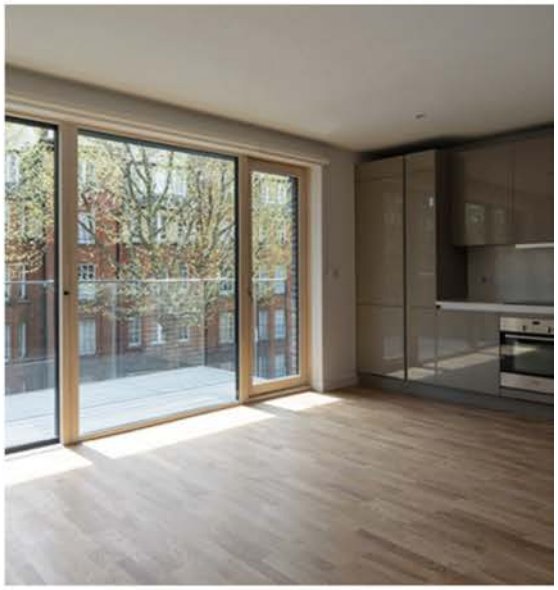
Number of Buildings	1
Total surface built (m²)	1800
Total surface built (f²)	19375
Structural category	Panelised timber-concrete (podium)
Podium	Up to 1 floor
Core	CLT
Floor slabs	CLT
Program	Residential
External Cladding	Bricks
Indoor elements exposed	None
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Sustainability
Architect	dRMM Architects, GB
Engineer	Robert Bird group, GB
Timber Engineer	Eurban, GB
General Contractor	Lendlease, INT
Timber Contractor	Eurban, GB
Timber Supplier:	
Structural Elements	Stora Enso, FI, SE
Floor Elements	Stora Enso, FI, SE
Client	Lendlease, INT

SOURCE OF IMAGES

Alex de Rijke, Lendlease, dRMM, Eurban



Wenlock Road 17-21

Year Completation	2015
Country	U.K.
City	London
Number of Storeys	10
Number Timber Storeys	9

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	6750
Total surface built (f²)	72657
Structural category	Panelised timber-concrete-steel (podium-core-steel frame)
Podium	Ground Floor
Core	Concrete
Floor slabs	CLT
Program	Residential
External Cladding	Wood
Indoor elements exposed	None
Building volume	Irregular

CONTEXTUAL DATA

Type of Commission	Competition
Influence	Private
Motivations	Sustainability
Architect	Hawkins Brown Architects, GB
Engineer	Pringuer James Engineers, GB
Timber Engineer	Pringuer James Engineers, GB
General Contractor	Regal Homes, GB
Timber Contractor	B & K Structures, GB
Timber Supplier:	
Structural Elements	Binderholz, AT
Floor Elements	Binderholz, AT
Client	Eurobuild Properties, GB

SOURCE OF IMAGES

Jack Hobhouse, Engenuiti

106 Lewes Road

Year Completation	2016
Country	U.K.
City	Brighton
Number of Storeys	5
Number Timber Storeys	4

DESIGN DATA

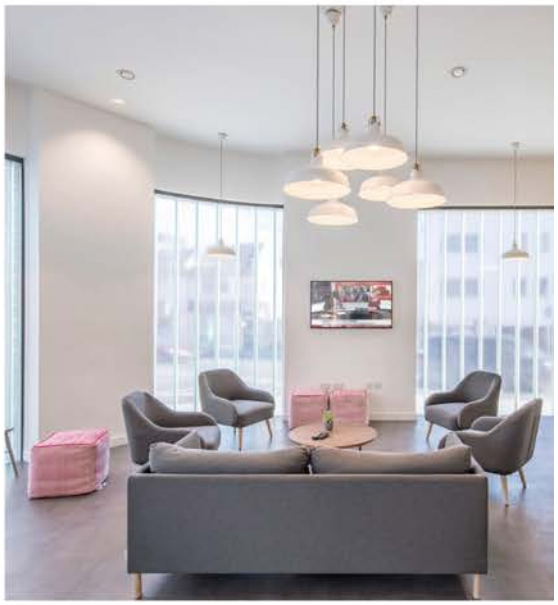
Number of Buildings	1
Total surface built (m²)	1650
Total surface built (f²)	17761
Structural category	Panelised timber-concrete (podium)
Podium	Ground Floor
Core	CLT
Floor slabs	CLT
Program	Student Housing
External Cladding	Bricks
Indoor elements exposed	None
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	n/a
Influence	Private
Motivations	n/a
Architect	Waugh Thistleton Architects, GB
Engineer	n/a
Timber Engineer	n/a
General Contractor	n/a
Timber Contractor	n/a
Timber Supplier:	
Structural Elements	Austria
Floor Elements	Austria
Client	McLaren, GB

SOURCE OF IMAGES

Waugh Thistleton Architects, Fourthdoor



Nordic Lofts

Year Completation	2016
Country	U.K.
City	London
Number of Storeys	5
Number Timber Storeys	5

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	520
Total surface built (f²)	5597
Structural category	Panelised all-timber
Podium	None
Core	CLT
Floor slabs	CLT
Program	Residential
External Cladding	Bricks
Indoor elements exposed	All the surfaces
Building volume	Pitched roof

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Technical aspects
Architect	Amin Taha Architects - Groupwork, GB
Engineer	Webb Yates Engineers, GB
Timber Engineer	Ecore Construction, GB
General Contractor	Ecore Construction, GB
Timber Contractor	Ecore Construction, GB
Timber Supplier:	
Structural Elements	Egoin, ES
Floor Elements	Egoin, ES
Client	Cobstar Development, GB

SOURCE OF IMAGES

Tim Soar, Nordic Loft, Webb Yates Engineers

UEA Blackdale

Year Completation	2016
Country	U.K.
City	Norwich
Number of Storeys	6
Number Timber Storeys	6

DESIGN DATA

Number of Buildings	2
Total surface built (m²)	16470
Total surface built (f²)	88642
Structural category	Panelised all-timber
Podium	None
Core	CLT
Floor slabs	CLT
Program	Student Housing
External Cladding	Metal
Indoor elements exposed	None
Building volume	Different heights

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Public
Motivations	Technical aspects
Architect	LSI Architects, GB
Engineer	Ramboll, GB
Timber Engineer	Ramboll, GB
General Contractor	RG Carter, GB
Timber Contractor	KLH, AT
Timber Supplier:	
Structural Elements	KLH, AT
Floor Elements	KLH, AT
Client	University East Anglia, GB

SOURCE OF IMAGES

Ramboll, LSI Architects

Woodberry Down

Year Completation	2016
Country	U.K.
City	London
Number of Storeys	5
Number Timber Storeys	5

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	1575
Total surface built (f²)	16953
Structural category	Panelised all-timber
Podium	None
Core	CLT
Floor slabs	CLT
Program	Residential
External Cladding	Bricks
Indoor elements exposed	Ceiling
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Technical aspects
Architect	Waugh Thistleton Architects, GB
Engineer	Eurban, GB
Timber Engineer	Eurban, GB
General Contractor	Berkeley Homes, GB
Timber Contractor	Eurban, GB
Timber Supplier:	
Structural Elements	Stora Enso, FI, SE
Floor Elements	Stora Enso, FI, SE
Client	Berkeley Homes, GB

SOURCE OF IMAGES

Eurban, Waugh Thistleton Architects

Bacton Low Rise

Year Completation	2017
Country	U.K.
City	London
Number of Storeys	5
Number Timber Storeys	5

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	7634
Total surface built (f²)	82172
Structural category	Panelised all-timber
Podium	None
Core	CLT
Floor slabs	CLT
Program	Residential
External Cladding	Bricks
Indoor elements exposed	None
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Public
Motivations	Sustainability
Architect	Karakusevic Carson Architects, GB
Engineer	Roltons, GB
Timber Engineer	Eurban, GB
General Contractor	Rydon, GB
Timber Contractor	Eurban, GB
Timber Supplier:	
Structural Elements	Stora Enso, FI, SE
Floor Elements	Stora Enso, FI, SE
Client	Camden Council, GB

SOURCE OF IMAGES

Building.co, Rydon, Eurban

Dalston Lane

Year Completation	2017
Country	U.K.
City	London
Number of Storeys	11
Number Timber Storeys	10

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	16000
Total surface built (f²)	172224
Structural category	Panelised timber-concrete (podium)
Podium	Ground Floor
Core	CLT
Floor slabs	CLT
Program	Residential
External Cladding	Bricks
Indoor elements exposed	None
Building volume	Different heights

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Technical aspects
Architect	Waugh Thistleton Architects, GB
Engineer	PJCE, GB
Timber Engineer	Ramboll, GB
General Contractor	Regal Homes, GB
Timber Contractor	B & K Structures, GB
Timber Supplier:	
Structural Elements	Binderholz, AT
Floor Elements	Binderholz, AT
Client	Regal London, GB

SOURCE OF IMAGES

Waugh Thistleton Architects, Binderholz

Highpoint Terrace

Year Completation	2017
Country	U.K.
City	London
Number of Storeys	8
Number Timber Storeys	8

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	12650
Total surface built (f²)	136165
Structural category	Panelised all-timber
Podium	None
Core	CLT
Floor slabs	CLT
Program	Residential - Social Housing
External Cladding	Metal
Indoor elements exposed	None
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	n/a
Influence	Private
Motivations	Technical aspects
Architect	Rogers Stirk Harbour and Partners - Axis Architects, GB
Engineer	n/a
Timber Engineer	Eurban, GB
General Contractor	n/a
Timber Contractor	Eurban, GB
Timber Supplier:	
Structural Elements	Stora Enso, FI, SE
Floor Elements	Stora Enso, FI, SE
Client	MACE - Peabody House Association, GB

SOURCE OF IMAGES

Eurban, Bim4CLT

Hands Building

Year Completation	2017
Country	U.K.
City	Oxford
Number of Storeys	5
Number Timber Storeys	4

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	2700
Total surface built (f²)	29063
Structural category	Panelised timber-concrete (podium)
Podium	Ground Floor
Core	CLT
Floor slabs	CLT
Program	Student Housing
External Cladding	Other
Indoor elements exposed	Walls
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	n/a
Influence	Private
Motivations	Sustainability
Architect	MICA Architects, GB
Engineer	Eckersley O'Callaghan, GB
Timber Engineer	Eurban, GB
General Contractor	Beard Construction, GB
Timber Contractor	Eurban, GB
Timber Supplier:	
Structural Elements	n/a
Floor Elements	n/a
Client	Mansfield College Developments, GB

SOURCE OF IMAGES

Mica Architects, Eckersley O'Callaghan

Press House

Year Completation	2017
Country	U.K.
City	London
Number of Storeys	9
Number Timber Storeys	8

DESIGN DATA

Number of Buildings	2
Total surface built (m²)	3750
Total surface built (f²)	40365
Structural category	Panelised timber-concrete (podium)
Podium	Ground Floor
Core	CLT
Floor slabs	CLT
Program	Residential
External Cladding	Bricks
Indoor elements exposed	None
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Sustainability
Architect	Geraghty Taylor, GB
Engineer	Eurban, GB
Timber Engineer	Eurban, GB
General Contractor	Henry Construction Projects, GB
Timber Contractor	Eurban, GB
Timber Supplier:	
Structural Elements	Binderholz, AT
Floor Elements	Binderholz, AT
Client	Network Homes, GB

SOURCE OF IMAGES

Geraghty Taylor

Boiler House

Year Completation	2018
Country	U.K.
City	London
Number of Storeys	7
Number Timber Storeys	6

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	4050
Total surface built (f²)	43594
Structural category	Panelised timber-concrete (podium)
Podium	Ground Floor
Core	CLT
Floor slabs	CLT
Program	Residential
External Cladding	Metal
Indoor elements exposed	None
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Sustainability
Architect	Stride Treglown, GB
Engineer	Eurban, GB
Timber Engineer	Eurban, GB
General Contractor	Henry Construction Projects, GB
Timber Contractor	Eurban, GB
Timber Supplier:	
Structural Elements	Binderholz, AT
Floor Elements	Binderholz, AT
Client	HUB - Realstar, GB

SOURCE OF IMAGES

Stride Treglown

Ellerslie Road

Year Completation	2018
Country	U.K.
City	Glasgow
Number of Storeys	7
Number Timber Storeys	7

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	4200
Total surface built (f²)	45209
Structural category	Panelised all-timber
Podium	None
Core	CLT
Floor slabs	CLT
Program	Residential - Social Housing
External Cladding	Bricks
Indoor elements exposed	None
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Public/Private
Motivations	Sustainability
Architect	Mast Architects, GB
Engineer	Smith and Wallwork Engineers, GB
Timber Engineer	Eurban, GB
General Contractor	Sanctuary Scotland, GB
Timber Contractor	Eurban, GB
Timber Supplier:	
Structural Elements	Stora Enso, FI, SE
Floor Elements	Stora Enso, FI, SE
Client	CCG, GB

SOURCE OF IMAGES

Mast Architects, Sanctuary Scotland

55 Pitfield Street

Year Completation	2019
Country	U.K.
City	London
Number of Storeys	6
Number Timber Storeys	5

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	3750
Total surface built (f²)	40365
Structural category	Panelised timber-concrete (podium)
Podium	Ground Floor
Core	CLT
Floor slabs	CLT
Program	Mixed Use (residential-other)
External Cladding	Bricks
Indoor elements exposed	None
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	n/a
Architect	Waugh Thistleton Architects, GB
Engineer	Elliott Wood, GB
Timber Engineer	Pryce & Myers - KLH, GB
General Contractor	Simply Construct, GB
Timber Contractor	KLH, AT
Timber Supplier:	
Structural Elements	KLH, AT
Floor Elements	KLH, AT
Client	Garfwish, GB

SOURCE OF IMAGES

Cinema Treasures, Waugh Thistleton Architects

Green House

Year Completation	2019
Country	U.K.
City	London
Number of Storeys	7
Number Timber Storeys	7

DESIGN DATA

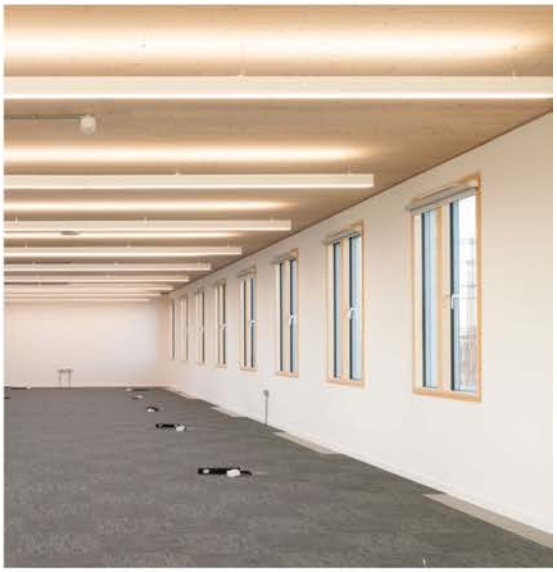
Number of Buildings	1
Total surface built (m²)	4645
Total surface built (f²)	50000
Structural category	Panelised all-timber
Podium	None
Core	CLT
Floor slabs	CLT
Program	Office
External Cladding	Plaster
Indoor elements exposed	None
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	n/a
Influence	Private
Motivations	n/a
Architect	Waugh Thistleton Architects, GB
Engineer	Ramboll, GB
Timber Engineer	Ramboll, GB
General Contractor	n/a
Timber Contractor	B & K Structures, GB
Timber Supplier:	
Structural Elements	Stora Enso, FI, SE
Floor Elements	Stora Enso, FI, SE
Client	Etichal Property, GB

SOURCE OF IMAGES

Waugh Thistleton Architects



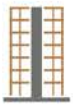
A.12 Canada

Project (name)	(image)	Storeys (number)	Timber Storeys (number)	Strucutral system (logo)	(category)	Core (material)	Floor Slabs (material)	Total Built Surface (m2)	Program (type)	Facade cladding (material)	Structural timber exposure (category)
CSN-Fondaction		6	6		Post-and-Beam timber-concrete (core)	Concrete	Glulam	5580	Office	Curtain wall	All the surfaces
UBC Earth Sciences		5	5		Post-and-Beam timber-concrete-steel (core-steel bracing)	Concrete	LSL-concrete	15794	Education	Metal	All the surfaces
District 03		6	6		Panelised all-timber and frame	CLT	CLT	5010	Residential	Metal	Ceiling
Wood Innovation Centre		8	8		Post-and-Beam all-timber	CLT	CLT	4820	Education	Wood	All the surfaces
Synergia		6	5		Post-and-Beam timber-concrete (podium-external bracing)	CLT	CLT	6689	Office	Curtain wall	All the surfaces
Arbora		8	7		Post-and-Beam timber-concrete (podium)	CLT	CLT	55515	Residential	Bricks	Columns and beams
Lakeside Resort Expansion		6	5		Post-and-Beam timber-concrete (podium)	CLT	CLT	11850	Hotel	Curtain wall	All the surfaces
Origine Condos		13	12		Panelised timber-concrete (podium and frame)	CLT	CLT	13124	Residential	Metal	None
UBC Brock Commons		18	17		Post and slab timber-concrete (podium-core)	Concrete	CLT	15115	Student Housing	Metal	None
Wilson School of Design		5	5		Post-and-Beam timber-concrete (core)	Concrete	CLT and Q-Deck-concrete	6503	Education	Curtain wall	All the surfaces

CSN-Fondaction

Year Completation	2009
Country	Canada
City	Quebec City
Number of Storeys	6
Number Timber Storeys	6

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	5580
Total surface built (f²)	60063
Structural category	 Post-and-Beam timber-concrete (core)
Podium	None
Core	Concrete
Floor slabs	Glulam
Program	Office
External Cladding	Curtain wall
Indoor elements exposed	All the surfaces
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Sustainability
Architect	Gilles Huot - GHA Atelier d'architecture, CA
Engineer	Bureau d'Études Spécialisées, CA
Timber Engineer	Nordic Structure, CA
General Contractor	Pomerlau, CA
Timber Contractor	Nordic Structure, CA
Timber Supplier:	
Structural Elements	Nordic Structure, CA
Floor Elements	Nordic Structure, CA
Client	CSN-Fondacion

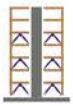
SOURCE OF IMAGES

Nordic Structure, BES, Radio Canada

UBC Earth Sciences

Year Completation	2012
Country	Canada
City	Vancouver
Number of Storeys	5
Number Timber Storeys	5

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	15794
Total surface built (f²)	170007
Structural category	 Post-and-Beam timber-concrete-steel (core-steel bracing)
Podium	None
Core	Concrete
Floor slabs	LSL-concrete
Program	Education
External Cladding	Metal
Indoor elements exposed	All the surfaces
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Public
Motivations	Sustainability
Architect	Perkins - Will, US, CA
Engineer	Equilibrium, CA
Timber Engineer	Equilibrium, CA - TiComTec, DE
General Contractor	Bird Construction, CA
Timber Contractor	Adera Construction - Nicola Logworks, CA
Timber Supplier:	
Structural Elements	Structurlam, CA
Floor Elements	Structurlam, CA
Client	University of British Columbia, CA

SOURCE OF IMAGES

Kimber Images, Forest Innovation Investment

District 03

Year Completation	2013
Country	Canada
City	Quebec City
Number of Storeys	6
Number Timber Storeys	6

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	5010
Total surface built (f²)	53928
Structural category	Panelised all-timber and frame
Podium	None
Core	CLT
Floor slabs	CLT
Program	Residential
External Cladding	Metal
Indoor elements exposed	Ceiling
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Technical aspects
Architect	Lemay, CA
Engineer	n/a
Timber Engineer	Nordic Structure, CA
General Contractor	n/a
Timber Contractor	Nordic Structure, CA
Timber Supplier:	
Structural Elements	Nordic Structure, CA
Floor Elements	Nordic Structure, CA
Client	n/a

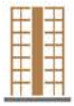
SOURCE OF IMAGES

Nordic Structures, Cecobois

Wood Innovation Centre

Year Completation	2014
Country	Canada
City	Vancouver
Number of Storeys	8
Number Timber Storeys	8

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	4820
Total surface built (f²)	51882
Structural category	 Post-and-Beam all-timber
Podium	None
Core	CLT
Floor slabs	CLT
Program	Education
External Cladding	Wood
Indoor elements exposed	All the surfaces
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Public
Motivations	Sustainability
Architect	Micheal Green Architects, CA
Engineer	Equilibrium, CA
Timber Engineer	Equilibrium, CA
General Contractor	PCL Constructors Westcoast, CA
Timber Contractor	Nicola Logworks, CA
Timber Supplier:	
Structural Elements	Structurlam, CA
Floor Elements	Structurlam, CA
Client	Province of British Columbia, CA

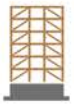
SOURCE OF IMAGES

Ema Peter, Ontario Erectors Association

Synergia

Year Completation	2016
Country	Canada
City	Saint-Hyacinthe
Number of Storeys	6
Number Timber Storeys	5

DESIGN DATA

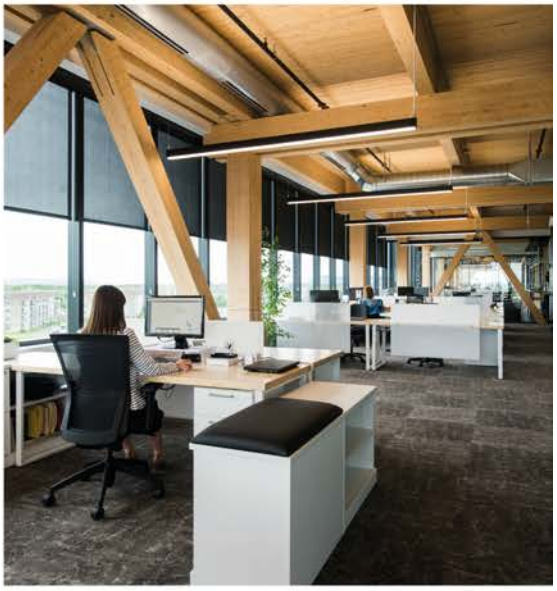
Number of Buildings	1
Total surface built (m²)	6689
Total surface built (f²)	72000
Structural category	 Post-and-Beam timber-concrete (podium-external bracing)
Podium	Ground Floor
Core	CLT
Floor slabs	CLT
Program	Office
External Cladding	Curtain wall
Indoor elements exposed	All the surfaces
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Sustainability
Architect	Lemay, CA
Engineer	n/a
Timber Engineer	Nordic Structure, CA
General Contractor	n/a
Timber Contractor	FGP Construction, CA
Timber Supplier:	
Structural Elements	Nordic Structure, CA
Floor Elements	Nordic Structure, CA
Client	Robin group, CA

SOURCE OF IMAGES

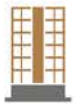
Myriam Lafrenière, Adrien Williams, Nordic Structures



Arbora

Year Completation	2017
Country	Canada
City	Montréal
Number of Storeys	8
Number Timber Storeys	7

DESIGN DATA

Number of Buildings	3
Total surface built (m²)	55515
Total surface built (f²)	597560
Structural category	 Post-and-Beam timber-concrete (podium)
Podium	Ground Floor
Core	CLT
Floor slabs	CLT
Program	Residential
External Cladding	Bricks
Indoor elements exposed	Columns and beams
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Sustainability
Architect	Lemay - CHA, CA
Engineer	n/a
Timber Engineer	Nordic Structure, CA
General Contractor	Sotramont, CA
Timber Contractor	FGP Construction, CA
Timber Supplier:	
Structural Elements	Nordic Structure, CA
Floor Elements	Nordic Structure, CA
Client	Sotramont, CA

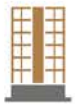
SOURCE OF IMAGES

Photographie Intérieure CO, Le studio Point de Vue, Alex Parent

Lakeside Resort Expansion

Year Completation	2017
Country	Canada
City	Penticton
Number of Storeys	6
Number Timber Storeys	5

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	11850
Total surface built (f²)	127553
Structural category	 Post-and-Beam timber-concrete (podium)
Podium	Ground Floor
Core	CLT
Floor slabs	CLT
Program	Hotel
External Cladding	Curtain wall
Indoor elements exposed	All the surfaces
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Sustainability
Architect	Nick Bevanda Architects, CA
Engineer	RJC Consulting Engineers, CA
Timber Engineer	Structurlam, CA
General Contractor	Greyback Construction, CA
Timber Contractor	n/a
Timber Supplier:	
Structural Elements	Structurlam, CA
Floor Elements	Structurlam, CA
Client	RPB Hotels, CA

SOURCE OF IMAGES

HDR, Eckert Electric

Origine Condos

Year Completation	2017
Country	Canada
City	Quebec City
Number of Storeys	13
Number Timber Storeys	12

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	13124
Total surface built (f²)	141267
Structural category	Panelised timber-concrete (podium and frame)
Podium	Ground Floor
Core	CLT
Floor slabs	CLT
Program	Residential
External Cladding	Metal
Indoor elements exposed	None
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Technical aspects
Architect	Yvan Blouin Architecture, CA
Engineer	WSP - Génécor, CA
Timber Engineer	Nordic Structure, CA
General Contractor	EBC, CA
Timber Contractor	FGP Construction, CA
Timber Supplier:	
Structural Elements	Nordic Structure, CA
Floor Elements	Nordic Structure, CA
Client	NEB Group, CA

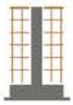
SOURCE OF IMAGES

Stéphane Groleau, FGP Construction, Nordic Strucutres

UBC Brock Commons

Year Completation	2017
Country	Canada
City	Vancouver
Number of Storeys	18
Number Timber Storeys	17

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	15115
Total surface built (f²)	162698
Structural category	 Post-and-Slab timber-concrete (podium-core)
Podium	Ground Floor
Core	Concrete
Floor slabs	CLT
Program	Student Housing
External Cladding	Metal
Indoor elements exposed	None
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Public
Motivations	Sustainability
Architect	Acton Ostry Architects, CA - Hermann Kaufmann, AT
Engineer	FAST - EPP, CA
Timber Engineer	FAST - EPP, CA
General Contractor	Urban One Builders, CA
Timber Contractor	Seagate Structures, CA
Timber Supplier:	
Structural Elements	Structurlam, CA
Floor Elements	Structurlam, CA
Client	University of Britich Columbia, CA

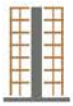
SOURCE OF IMAGES

Acton Ostry Architects

Wilson School of Design

Year Completation	2018
Country	Canada
City	Richmond
Number of Storeys	5
Number Timber Storeys	5

DESIGN DATA

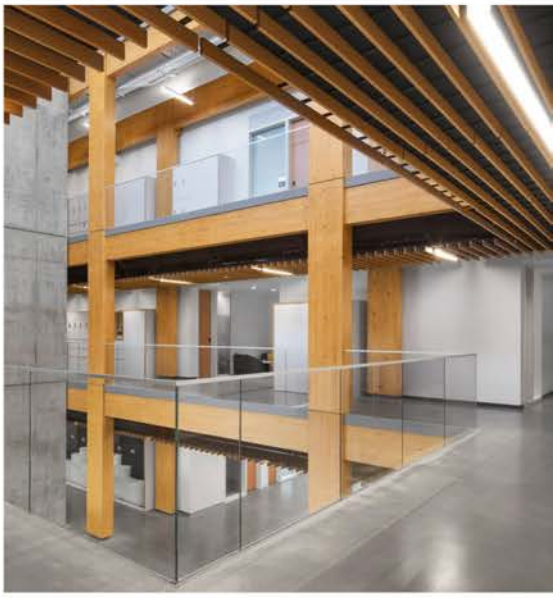
Number of Buildings	1
Total surface built (m²)	6503
Total surface built (f²)	69998
Structural category	 Post-and-Beam timber-concrete (core)
Podium	None
Core	Concrete
Floor slabs	CLT and Q-Deck-concrete
Program	Education
External Cladding	Curtain wall
Indoor elements exposed	All the surfaces
Building volume	Regular

CONTEXTUAL DATA

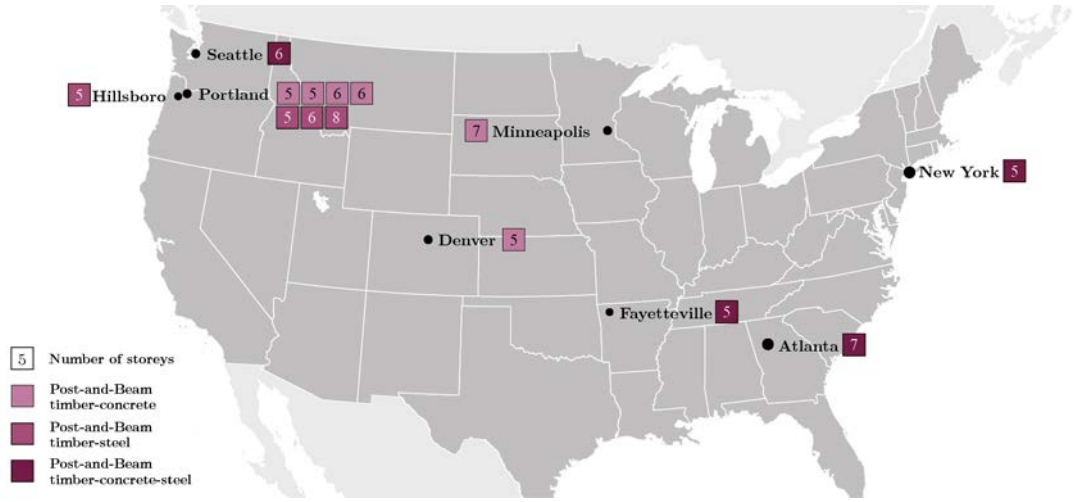
Type of Commission	n/a
Influence	Public/Private
Motivations	Sustainability
Architect	KPMB Architects - Public Architecture, CA
Engineer	Core Group, CA
Timber Engineer	FAST - EPP, CA
General Contractor	DGS Construction, CA
Timber Contractor	Seagate Structures, CA
Timber Supplier:	
Structural Elements	Binderholz, AT
Floor Elements	Binderholz, AT
Client	Kwantlen Polytechnic University, CA

SOURCE OF IMAGES

Andrew Latreille, Lignum Design



A.13 United States of America



Project (name)	(image)	Storeys (number)	Timber Storeys (number)	Structutral system (logo)	(category)	Core (material)	Floor Slabs (material)	Total Built Surface (m2)	Program (type)	Facade cladding (material)	Structural timber exposure (category)
Bullitt Center		6	4		Post-and-Beam timber-concrete-steel (podium-core-steel bracing)	Steel Frame	NLT	4831	Office	Metal	All the surfaces
Radiator		5	5		Post-and-Beam timber-steel (steel core and bracing)	Steel Frame	NLT	3279	Office	Metal	All the surfaces
Framework		5	4		Post-and-Beam timber-concrete (podium-core)	Concrete	Tongue and groove decking	2323	Office	Curtain wall	All the surfaces
38 Davis		6	5		Post-and-Beam timber-concrete (podium)	None	NLT	12077	Mixed Use (residential-office)	Bricks	All the surfaces
Clay Creative		6	6		Post-and-Beam timber-steel (external frame)	None	NLT-concrete	8361	Office	Bricks	All the surfaces
T3		7	6		Post-and-Beam timber-concrete (podium-core)	Concrete	NLT-concrete	16722	Office	Metal	All the surfaces
360 Wythe		5	5		Post-and-Beam timber-concrete-steel (core-steel bracing)	Concrete	NLT	6039	Office	Bricks	All the surfaces
Carbon 12		8	8		Post-and-Beam timber-steel (steel core and bracing)	Steel Frame	CLT	3902	Residential	Metal	All the surfaces
First Tech Federal Credit Union		5	5		Post-and-Beam timber-steel (steel core and bracing)	Steel Frame	CLT	14493	Office	Metal	All the surfaces
Flatiron PDX		6	4		Post-and-Beam timber-concrete (podium-core)	Concrete	CLT-concrete	2601	Mixed Use (residential-office)	Metal	All the surfaces
Adohi Hall		5	4		Post-and-Beam timber-concrete-steel (steel podium-core)	Concrete	CLT	18769	Student Housing	Metal	All the surfaces
Platte Fifteen		5	4		Post-and-Beam timber-concrete (podium-core)	Concrete	CLT	13974	Office	Bricks	All the surfaces
Sideyard		5	5		Post-and-Beam timber-concrete (core)	Concrete	CLT	1858	Office	Bricks	All the surfaces
T3 Atlanta		7	6		Post-and-Beam timber-concrete-steel (podium-steel bracing)	None	DLT	19045	Office	Curtain wall	All the surfaces

Bullitt Center

Year Completation	2013
Country	USA
City	Seattle
Number of Storeys	6
Number Timber Storeys	4

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	4831
Total surface built (f²)	52000
Structural category	Post-and-Beam timber-concrete-steel (podium-core-steel bracing)
Podium	Up to first floor
Core	Steel Frame
Floor slabs	NLT
Program	Office
External Cladding	Metal
Indoor elements exposed	All the surfaces
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Sustainability
Architect	The Miller Hull Partnership, US
Engineer	DCI Engineers, US
Timber Engineer	DCI Engineers, US
General Contractor	Schuchart, US
Timber Contractor	Calvert Glulam, US
Timber Supplier:	
Structural Elements	Calvert Glulam, US
Floor Elements	Calvert Glulam, US
Client	The Bullitt Foundation, US

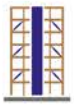
SOURCE OF IMAGES

John Stamets

Radiator

Year Completation	2014
Country	USA
City	Portland
Number of Storeys	5
Number Timber Storeys	5

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	3279
Total surface built (f²)	35300
Structural category	 Post-and-Beam timber-steel (steel core and bracing)
Podium	None
Core	Steel Frame
Floor slabs	NLT
Program	Office
External Cladding	Metal
Indoor elements exposed	All the surfaces
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Sustainability
Architect	PATH Architecture, US
Engineer	Munzing Structural Engineers, US
Timber Engineer	Munzing Structural Engineers, US
General Contractor	Kaiser Group, US
Timber Contractor	Timberland Framing, US
Timber Supplier:	
Structural Elements	Rosboro, US
Floor Elements	Rosboro, US
Client	Kaiser Group, US

SOURCE OF IMAGES

Keiser+Path, PATH Architecture

Framework

Year Completation	2015
Country	USA
City	Portland
Number of Storeys	5
Number Timber Storeys	4

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	2323
Total surface built (f²)	25000
Structural category	Post-and-Beam timber-concrete (podium-core)
Podium	Ground Floor
Core	Concrete
Floor slabs	Tongue and groove decking, laid diagonally
Program	Office
External Cladding	Curtain wall
Indoor elements exposed	All the surfaces
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Sustainability
Architect	Work Progress Architecture, US
Engineer	TM Rippey Engineers - Don Cushing Associates, US
Timber Engineer	Frank Lumber Company, US
General Contractor	Yorke and Curtis, US
Timber Contractor	Frank Lumber Company, US
Timber Supplier:	
Structural Elements	Frank Lumber Company, US
Floor Elements	Frank Lumber Company, US
Client	Urban Development Partners, US

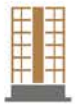
SOURCE OF IMAGES

Archdaily, Joshua Jay Elliot

38 Davis

Year Completation	2016
Country	USA
City	Portland
Number of Storeys	6
Number Timber Storeys	5

DESIGN DATA

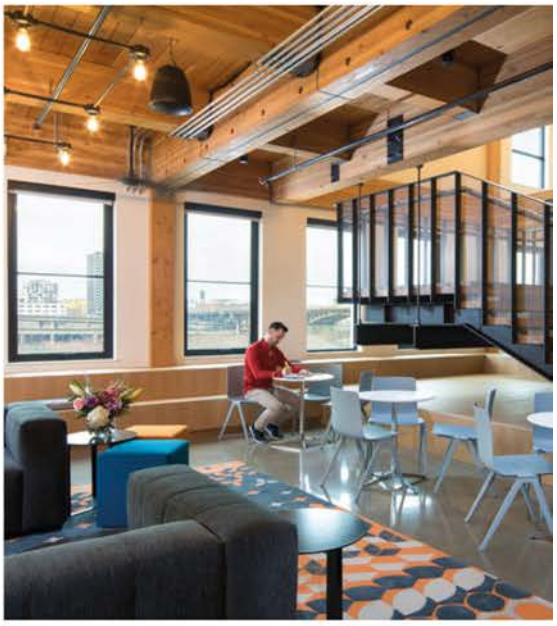
Number of Buildings	1
Total surface built (m²)	12077
Total surface built (f²)	130000
Structural category	 Post-and-Beam timber-concrete (podium)
Podium	Ground Floor
Core	None
Floor slabs	NLT
Program	Mixed Use (residential-office)
External Cladding	Bricks
Indoor elements exposed	All the surfaces
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Sustainability
Architect	Ankrom Moisan Architects, US
Engineer	Humber Design Group, US
Timber Engineer	DCI Engineers, US
General Contractor	Andersen Construction, US
Timber Contractor	n/a
Timber Supplier:	
Structural Elements	Local
Floor Elements	Local
Client	Gerding Edlen, US

SOURCE OF IMAGES

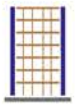
Ankrom Moisan Architect, Andersen Construction



Clay Creative

Year Completation	2016
Country	USA
City	Portland
Number of Storeys	6
Number Timber Storeys	6

DESIGN DATA

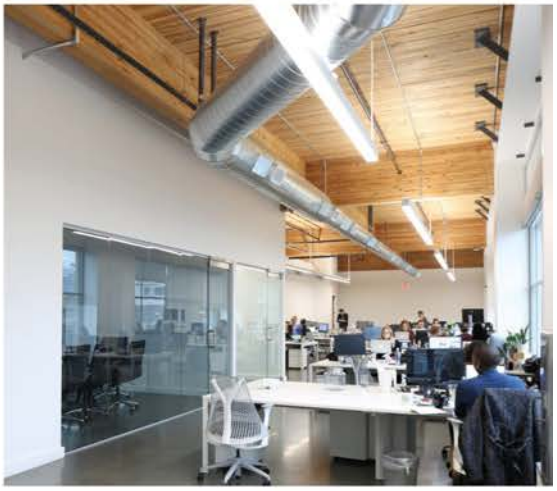
Number of Buildings	1
Total surface built (m²)	8361
Total surface built (f²)	90000
Structural category	 Post-and-Beam timber-steel (external frame)
Podium	None
Core	None
Floor slabs	NLT-concrete
Program	Office
External Cladding	Bricks
Indoor elements exposed	All the surfaces
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Sustainability
Architect	Mackenzie Architects, US
Engineer	Kramer Gehlen & Associates, US
Timber Engineer	Kramer Gehlen \& Associates, US
General Contractor	Turner Construction Company, US
Timber Contractor	Turner Construction Company, US
Timber Supplier:	
Structural Elements	n/a
Floor Elements	n/a
Client	Killan Pacific, US

SOURCE OF IMAGES

ThinkWood, Mackenzie Architects, OregonMetro



T3

Year Completation	2016
Country	USA
City	Minneapolis
Number of Storeys	7
Number Timber Storeys	6

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	16722
Total surface built (f²)	180000
Structural category	Post-and-Beam timber-concrete (podium-core)
Podium	Ground Floor
Core	Concrete
Floor slabs	NLT-concrete
Program	Office
External Cladding	Metal
Indoor elements exposed	All the surfaces
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Sustainability
Architect	Micheal Green Architects, CA - DLR Group, US
Engineer	Magnusson Klemencic Associates, US
Timber Engineer	Structure Craft, CA
General Contractor	Kraus Anderson Construction, US
Timber Contractor	Structure Craft, CA
Timber Supplier:	
Structural Elements	Hasslacher Nordica Timber, AT
Floor Elements	Structure Craft, CA
Client	Hines, US

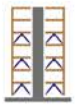
SOURCE OF IMAGES

Ema Peter, Structurecraft

360 Wythe

Year Completation	2018
Country	USA
City	New York
Number of Storeys	5
Number Timber Storeys	5

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	6039
Total surface built (f²)	65000
Structural category	 Post-and-Beam timber-concrete-steel (core-steel bracing)
Podium	None
Core	Concrete
Floor slabs	NLT
Program	Office
External Cladding	Bricks
Indoor elements exposed	All the surfaces
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Sustainability
Architect	Flank, US
Engineer	Tharpe, US
Timber Engineer	Nordic Structure, CA
General Contractor	n/a
Timber Contractor	FGP Construction, CA
Timber Supplier:	
Structural Elements	Nordic Structure, CA
Floor Elements	Nordic Structure, CA
Client	Flank, US

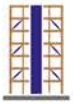
SOURCE OF IMAGES

Costar Group, Entuitive, FGP Construction

Carbon 12

Year Completation	2018
Country	USA
City	Portland
Number of Storeys	8
Number Timber Storeys	8

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	3902
Total surface built (f²)	42000
Structural category	 Post-and-Beam timber-steel (steel core and bracing)
Podium	None
Core	Steel Frame
Floor slabs	CLT
Program	Residential
External Cladding	Metal
Indoor elements exposed	All the surfaces
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Public/Private
Motivations	Sustainability
Architect	PATH Architecture, US
Engineer	Munzing Structural Engineers, US
Timber Engineer	Munzing Structural Engineers, US
General Contractor	Kaiser Group, US
Timber Contractor	Structurlam, CA
Timber Supplier:	
Structural Elements	Structurlam, CA
Floor Elements	Structurlam, CA
Client	Kaiser Group, US

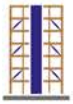
SOURCE OF IMAGES

carbon12pdx.com, Path Architecture

First Tech Federal Credit Union

Year Completation	2018
Country	USA
City	Hillsboro
Number of Storeys	5
Number Timber Storeys	5

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	14493
Total surface built (f²)	156000
Structural category	 Post-and-Beam timber-steel (steel core and bracing)
Podium	None
Core	Steel Frame
Floor slabs	CLT
Program	Office
External Cladding	Metal
Indoor elements exposed	All the surfaces
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Sustainability
Architect	Hacker, US
Engineer	Kramer Gehlen & Associates, US
Timber Engineer	Kramer Gehlen & Associates, US - Equilibrium Consulting, CA
General Contractor	Swinerton Builders, US
Timber Contractor	Structurlam, CA
Timber Supplier:	
Structural Elements	Structurlam, CA
Floor Elements	Structurlam, CA
Client	First Tech Federal Credit Union, US

SOURCE OF IMAGES

Jeremy Bittermann, Structurlam

Flatiron PDX

Year Completation	2018
Country	USA
City	Portland
Number of Storeys	6
Number Timber Storeys	4

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	2601
Total surface built (f²)	28000
Structural category	Post-and-Beam timber-concrete (podium-core)
Podium	Up to 1 floor
Core	Concrete
Floor slabs	CLT-concrete
Program	Mixed Use (residential-office)
External Cladding	Metal
Indoor elements exposed	All the surfaces
Building volume	Irregular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Technical aspects
Architect	Work Progress Architecture, US
Engineer	DCI Engineers, US
Timber Engineer	DCI Engineers, US
General Contractor	Abbott Construction, US
Timber Contractor	Structurlam, CA
Timber Supplier:	
Structural Elements	Structurlam, CA
Floor Elements	Structurlam, CA
Client	n/a

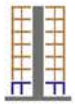
SOURCE OF IMAGES

Lincoln Barbour, Stucturelam

Adohi Hall

Year Completation	2019
Country	USA
City	Fayetteville
Number of Storeys	5
Number Timber Storeys	4

DESIGN DATA

Number of Buildings	2
Total surface built (m²)	18769
Total surface built (f²)	202027
Structural category	 Post-and-Beam timber-concrete-steel (steel podium-core)
Podium	Ground Floor (Steel)
Core	Concrete
Floor slabs	CLT
Program	Student Housing
External Cladding	Metal
Indoor elements exposed	All the surfaces
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Public
Motivations	Sustainability
Architect	Leers Weinzapfel Associates, US
Engineer	Holzapak, US
Timber Engineer	Holzapak, US
General Contractor	Nabholz, US
Timber Contractor	Holzapak, US
Timber Supplier:	
Structural Elements	Binderholz, AT
Floor Elements	Binderholz, AT
Client	University Arkansas, US

SOURCE OF IMAGES

Timothy Hursley, MackeyMitchell

Platte Fifteen

Year Completation	2019
Country	USA
City	Denver
Number of Storeys	5
Number Timber Storeys	4

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	13974
Total surface built (f²)	150418
Structural category	Post-and-Beam timber-concrete (podium-core)
Podium	Ground Floor
Core	Concrete
Floor slabs	CLT
Program	Office
External Cladding	Bricks
Indoor elements exposed	All the surfaces
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Sustainability
Architect	OZ Architecture, US
Engineer	KL&A, US
Timber Engineer	KL&A, US
General Contractor	Adolfson & Peterson Construction, US
Timber Contractor	FGP Construction, CA
Timber Supplier:	
Structural Elements	Nordic Structure, CA
Floor Elements	Nordic Structure, CA
Client	Crescent Real Estate, US

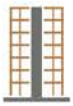
SOURCE OF IMAGES

KL&A, FGP Construction

Sidewalk

Year Completation	2019
Country	USA
City	Portland
Number of Storeys	5
Number Timber Storeys	5

DESIGN DATA

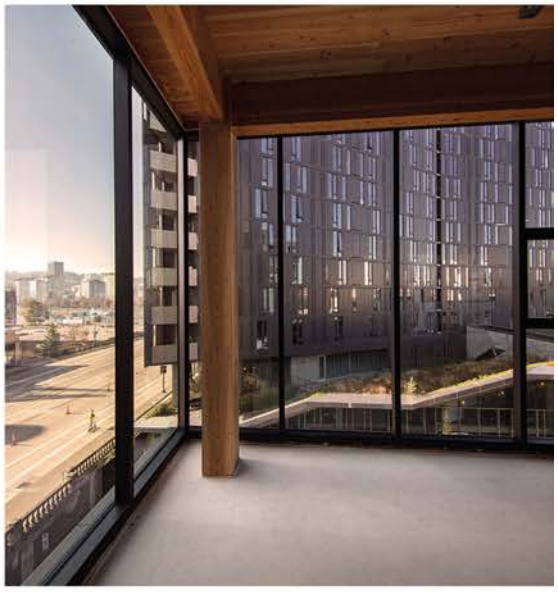
Number of Buildings	1
Total surface built (m²)	1858
Total surface built (f²)	20000
Structural category	 Post-and-Beam timber-concrete (core)
Podium	None
Core	Concrete
Floor slabs	CLT
Program	Office
External Cladding	Bricks
Indoor elements exposed	All the surfaces
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Technical aspects
Architect	Skylab Architecture, US
Engineer	Harper Houf Peterson Righellis, US
Timber Engineer	catena engineers, US
General Contractor	Andersen Construction, US
Timber Contractor	DR Johnson, US
Timber Supplier:	
Structural Elements	DR Johnson, US
Floor Elements	DR Johnson, US
Client	Key Development, US

SOURCE OF IMAGES

Stephen Miller



T3 Atalanta

Year Completation	2019
Country	USA
City	Atlanta
Number of Storeys	7
Number Timber Storeys	6

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	19045
Total surface built (f²)	205000
Structural category	Post-and-Beam timber-concrete-steel (podium-steel bracing)
Podium	Ground Floor
Core	None
Floor slabs	DLT
Program	Office
External Cladding	Curtain wall
Indoor elements exposed	All the surfaces
Building volume	Regular

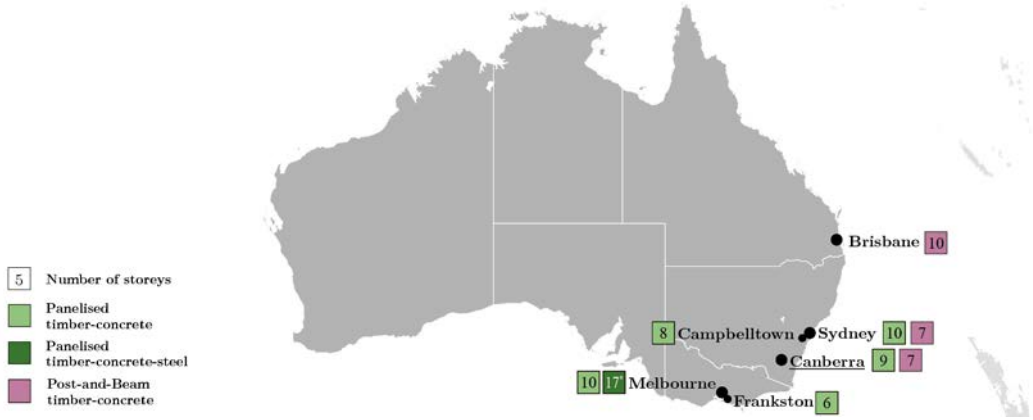
CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Sustainability
Architect	Hartshorne Plunkard Architects - DLR Group, US
Engineer	Magnusson Klemencic Associates, US
Timber Engineer	Structure Craft, CA
General Contractor	New South Construction, US
Timber Contractor	Structure Craft, CA
Timber Supplier:	
Structural Elements	Structure Craft, CA
Floor Elements	Structure Craft, CA
Client	Hines, US

SOURCE OF IMAGES

Hines, DLR Group

A.14 Australia

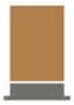


Project (name)	(image)	Storeys (number)	Timber Storeys (number)	Strucutral system (logo)	(category)	Core (material)	Floor Slabs (material)	Total Built Surface (m2)	Program (type)	Facade cladding (material)	Structural timber exposure (category)
Forté		10	9		Panelised timber-concrete (podium)	CLT	CLT	2890	Residential	Metal	Walls
25 King		10	9		Post-and-Beam timber-concrete (podium-external bracing)	CLT	CLT	14921	Office	Curtain wall	All the surfaces
Aveo Norwest		10	8		Panelised timber-concrete (podium)	CLT	CLT	18510	Senior living	Other	None
Daramu House		7	6		Post-and-Beam timber-concrete (podium-external bracing)	CLT	CLT	10000	Office	Curtain wall	All the surfaces
The Gardens Macarthur		8	7		Panelised timber-concrete (podium)	CLT	CLT	22000	Residential - Social Housing	Metal	n/a
55 Southbank Boulevard		17	10		Panelised timber-concrete-steel (podium-core)	CLT	CLT	14493	Hotel	Curtain wall	None
Gillies Hall		6	5		Panelised timber-concrete (podium)	CLT	CLT	6500	Student Housing	Metal	Ceiling
Kambri-Student accomodation		9	6		Panelised timber-concrete (podium)	CLT	CLT	22000	Student Housing	Bricks	Walls
Kambri-CLE		7	6		Post-and-Beam timber-concrete (podium-external bracing)	CLT	Cassette floor system	8575	Education	Curtain wall	All the surfaces

Forté

Year Completation	2012
Country	Australia
City	Melbourne
Number of Storeys	10
Number Timber Storeys	9

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	2890
Total surface built (f²)	31108
Structural category	 Panelised timber-concrete (podium)
Podium	Ground Floor
Core	CLT
Floor slabs	CLT
Program	Residential
External Cladding	Metal
Indoor elements exposed	Walls
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Sustainability
Architect	Lendlease, INT
Engineer	Lendlease - DesignMake, INT
Timber Engineer	KLH, AT
General Contractor	Lendlease, INT
Timber Contractor	KLH, AT
Timber Supplier:	
Structural Elements	KLH, AT
Floor Elements	KLH, AT
Client	Lendlease, INT

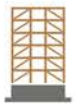
SOURCE OF IMAGES

Lendlease, Emma Cross Photographer, KLH

25 King

Year Completation	2018
Country	Australia
City	Brisbane
Number of Storeys	10
Number Timber Storeys	9

DESIGN DATA

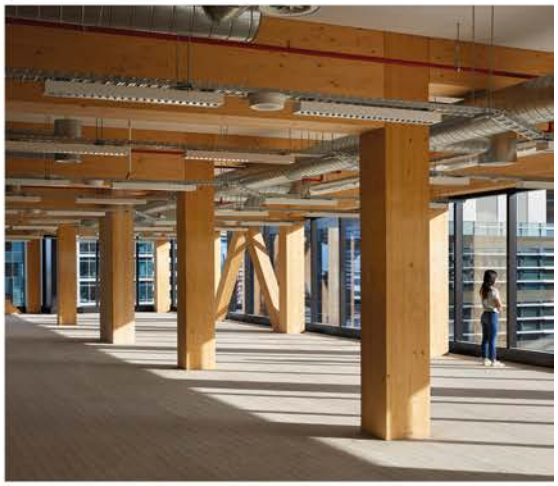
Number of Buildings	1
Total surface built (m²)	14921
Total surface built (f²)	160610
Structural category	 Post-and-Beam timber-concrete (podium-external bracing)
Podium	Ground Floor
Core	CLT
Floor slabs	CLT
Program	Office
External Cladding	Curtain wall
Indoor elements exposed	All the surfaces
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Sustainability
Architect	Bates Smart Architects, AU
Engineer	Lendlease - DesignMake, INT
Timber Engineer	Lendlease - DesignMake, INT
General Contractor	Lendlease, INT
Timber Contractor	Lendlease, INT
Timber Supplier:	
Structural Elements	Wiehag, AT
Floor Elements	Stora Enso, FI, SE
Client	Lendlease, INT

SOURCE OF IMAGES

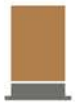
Bates Smart Architects, AECOM, Tom Roe



Aveo Norwest

Year Completation	2018
Country	Australia
City	Bella Vista - Sydney
Number of Storeys	10
Number Timber Storeys	8

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	18510
Total surface built (f²)	199242
Structural category	 Panelised timber-concrete (podium)
Podium	Up to first floor
Core	CLT
Floor slabs	CLT
Program	Senior living
External Cladding	Other
Indoor elements exposed	None
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Building erection speed
Architect	Jackson Teece, AU
Engineer	Taylor Thomson Whitting, AU
Timber Engineer	Taylor Thomson Whitting, AU
General Contractor	Strongbuild, AU
Timber Contractor	Strongbuild, AU
Timber Supplier:	
Structural Elements	Binderholz, AT
Floor Elements	Binderholz, AT
Client	AVEO, AU

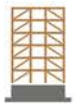
SOURCE OF IMAGES

Strongbuild, Taylor Thomson Whitting

Daramu House

Year Completation	2018
Country	Australia
City	Sydney
Number of Storeys	7
Number Timber Storeys	6

DESIGN DATA

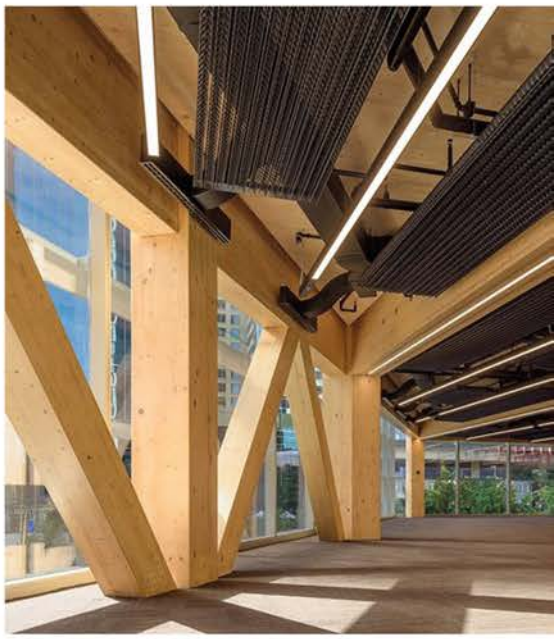
Number of Buildings	1
Total surface built (m²)	10000
Total surface built (f²)	107640
Structural category	 Post-and-Beam timber-concrete (podium-external bracing)
Podium	Ground Floor
Core	CLT
Floor slabs	CLT
Program	Office Curtain wall All the surfaces
External Cladding	Regular
Indoor elements exposed	
Building volume	

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Technical aspects
Architect	Tzannes Architects, AU
Engineer	Lendlease - DesignMake, Arcadis - WSP - AECOM, INT
Timber Engineer	Lendlease - DesignMake, INT
General Contractor	Lendlease, INT
Timber Contractor	Lendlease, INT
Timber Supplier:	
Structural Elements	Hess Timber, DE
Floor Elements	Stora Enso, FI, SE
Client	Lendlease, INT

SOURCE OF IMAGES

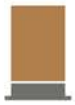
Tzannes Architects, Ben Guthrie, Brett Boardman, Michael Nicholson



The Gardens Macarthur

Year Completation	2018
Country	Australia
City	Campbelltown
Number of Storeys	8
Number Timber Storeys	7

DESIGN DATA

Number of Buildings	3
Total surface built (m²)	22000
Total surface built (f²)	236808
Structural category	 Panelised timber-concrete (podium)
Podium	Ground Floor
Core	CLT
Floor slabs	CLT
Program	Residential - Social Housing
External Cladding	Metal
Indoor elements exposed	n/a
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Technical aspects
Architect	n/a
Engineer	AECOM, INT
Timber Engineer	AECOM, INT
General Contractor	Strongbuild, AU
Timber Contractor	Strongbuild, AU
Timber Supplier:	
Structural Elements	Binderholz, AT
Floor Elements	Binderholz, AT
Client	BlueCHP, AU

SOURCE OF IMAGES

Storngbuild, Binderholz

55 Southbank Boulevard

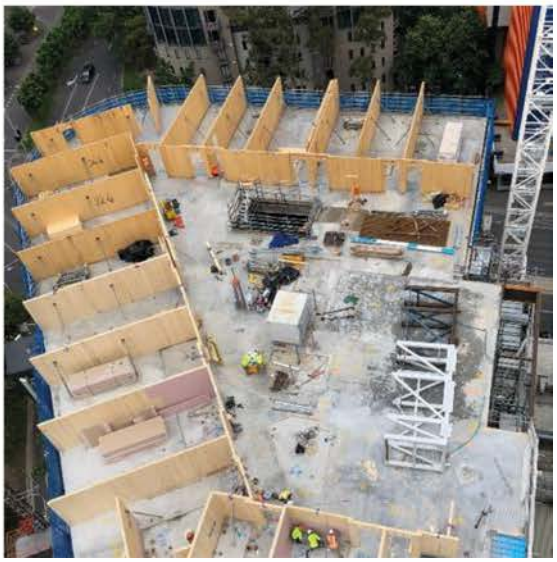
Year Completation	2019
Country	Australia
City	Melbourne
Number of Storeys	17
Number Timber Storeys	10

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	14493
Total surface built (f²)	156003
Structural category	Panelised timber-concrete-steel (podium-core)
Podium	Addition existing building
Core	CLT
Floor slabs	CLT
Program	Hotel
External Cladding	Curtain wall
Indoor elements exposed	None
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Technical aspects
Architect	Bates Smart Architects, AU
Engineer	WSP, AU
Timber Engineer	Vistek, AU
General Contractor	Atelier Projects, AU
Timber Contractor	KLH, AT
Timber Supplier:	
Structural Elements	KLH, AT
Floor Elements	KLH, AT
Client	Hume Propety Group, AU



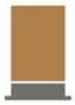
SOURCE OF IMAGES

Bates Smart Architects, Adina Apartment Hotel Melbourne Southbank, Vistek

Gillies Hall

Year Completation	2019
Country	Australia
City	Frankston
Number of Storeys	6
Number Timber Storeys	5

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	6500
Total surface built (f²)	69966
Structural category	 Panelised timber-concrete (podium)
Podium	Ground Floor
Core	CLT
Floor slabs	CLT
Program	Student Housing
External Cladding	Metal
Indoor elements exposed	Ceiling
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Competition
Influence	Public
Motivations	Sustainability
Architect	Jackson Clements Burrows Architects, AU
Engineer	AECOM, INT
Timber Engineer	AECOM, INT
General Contractor	Multiplex, AU
Timber Contractor	Xlam Dolomiti, IT
Timber Supplier:	
Structural Elements	Xlam Dolomiti, IT
Floor Elements	Xlam Dolomiti, IT
Client	Monash University - MRS, AU

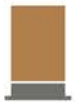
SOURCE OF IMAGES

Peter Clarke, JCB Architects, Xlam Dolomiti

Kambri - Student Building

Year Completation	2019
Country	Australia
City	Canberra
Number of Storeys	9
Number Timber Storeys	6

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	22000
Total surface built (f²)	236808
Structural category	 Panelised timber-concrete (podium)
Podium	Up to first floor
Core	CLT
Floor slabs	CLT
Program	Student Housing
External Cladding	Bricks
Indoor elements exposed	Walls
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Competition
Influence	Public
Motivations	Technical aspects
Architect	BVN Architects, AU
Engineer	Robert Bird Group, AU
Timber Engineer	Lendlease - DesignMake, INT
General Contractor	Lendlease, INT
Timber Contractor	ABS, AU
Timber Supplier:	
Structural Elements	Stora Enso, FI, SE
Floor Elements	Stora Enso, FI, SE
Client	The Australian National Univesity, AU

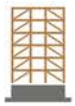
SOURCE OF IMAGES

Lendlease, Brett Boardman, John Gollings, Jamie Kidston

Kambri- Campus Building

Year Completation	2019
Country	Australia
City	Canberra
Number of Storeys	7
Number Timber Storeys	6

DESIGN DATA

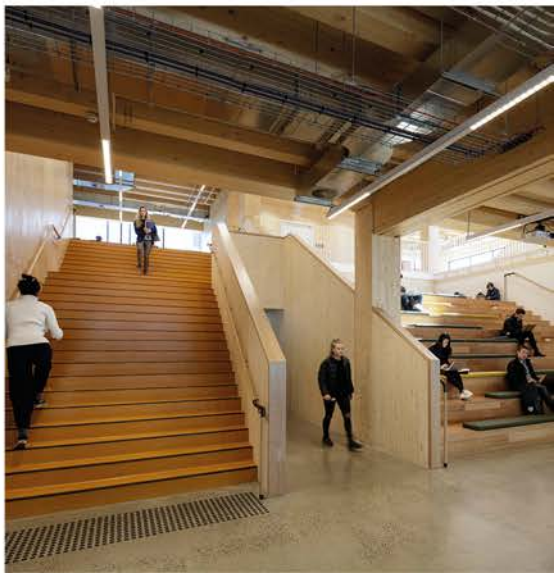
Number of Buildings	1
Total surface built (m²)	8575
Total surface built (f²)	92301
Structural category	 Post-and-Beam timber-concrete (podium-external bracing)
Podium	Ground Floor
Core	CLT
Floor slabs	Cassette floor system
Program	Education
External Cladding	Curtain wall
Indoor elements exposed	All the surfaces
Building volume	Regular

CONTEXTUAL DATA

Type of Commission	Competition
Influence	Public
Motivations	Technical aspects
Architect	BVN Architects, AU
Engineer	Robert Bird Group, AU
Timber Engineer	Lendlease - DesignMake, INT
General Contractor	Lendlease, INT
Timber Contractor	ABS, AU
Timber Supplier:	
Structural Elements	Stora Enso, FI, SE
Floor Elements	Stora Enso, FI, SE
Client	The Australian National Univesity, AU

SOURCE OF IMAGES

Lendlease, John Gollings



A.15 Other Countries

Project (name)	(image)	Storeys (number)	Timber Storeys (number)	Strucutral system (logo)	(category)	Core (material)	Floor Slabs (material)	Total Built Surface (m2)	Program (type)	Facade cladding (material)	Structural timber exposure (category)
Te Ara Hihiko		5	3		Post-and-Beam timber-concrete-steel (podium-steel rods)	None	LVL-concrete	3500	Education	Curtain wall	All the surfaces
WoodTek HQ		5	4		Panelised timber-concrete (podium)	CLT	CLT	600	Office	Metal	All the surfaces
Los Bronces		6	6		3D Modular element all-timber	None	Box element	36980	Hotel	Wood	All the surfaces

Te Ara Hihiko

Year Completation	2012
Country	New Zeland
City	Christchurch
Number of Storeys	5
Number Timber Storeys	3

DESIGN DATA

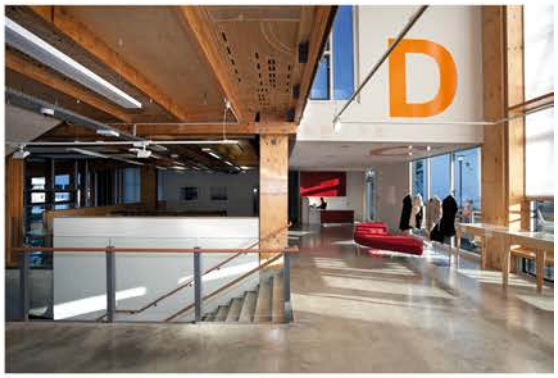
Number of Buildings	1
Total surface built (m²)	3500
Total surface built (f²)	37674
Structural category	Post-and-beam timber-concrete-steel (podium-core-steel rods)
Podium	Up to 1 floor
Core	Concrete
Floor slabs	LVL-Concrete
Program	Education
External Cladding	Curtain wall
Indoor elements exposed	All the surfaces
Building volume	Different heights

CONTEXTUAL DATA

Type of Commission	Competition
Influence	Public
Motivations	Technical aspects
Architect	Athfield Architects, NZ
Engineer	Dunning Thornton Consultants, NZ
Timber Engineer	Dunning Thornton Consultants, NZ
General Contractor	Arrow International, NZ
Timber Contractor	Arrow International, NZ
Timber Supplier:	
Structural Elements	Nelson Pine Industries - Hunter Laminates, NZ
Floor Elements	Nelson Pine Industries - Hunter Laminates, NZ
Client	Massey University, NZ

SOURCE OF IMAGES

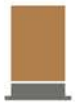
Trends Publishing, Matt Paterson, Massey University



WoodTek HQ

Year Completation	2014
Country	Taiwan
City	Taichung City
Number of Storeys	5
Number Timber Storeys	4

DESIGN DATA

Number of Buildings	1
Total surface built (m²)	600
Total surface built (f²)	6458
Structural category	 Panelised timber-concrete (podium)
Podium	Ground Floor
Core	CLT
Floor slabs	CLT
Program	Office
External Cladding	Metal
Indoor elements exposed	All the surfaces
Building volume	Irregular

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Sustainability
Architect	Origin, TW
Engineer	n/a
Timber Engineer	Equilibrium - Nicola Logworks, CA
General Contractor	Shaing-Yang Construction, TW
Timber Contractor	KLH, AT
Timber Supplier:	
Structural Elements	KLH, AT
Floor Elements	KLH, AT
Client	WoodTek, TW

SOURCE OF IMAGES

Figure x Lee Kuo-Min Studio, WoodTek

Los Bronces

Year Completation	2019
Country	Chile
City	Los Andes, Valparaíso
Number of Storeys	6
Number Timber Storeys	6

DESIGN DATA

Number of Buildings	8
Total surface built (m²)	36980
Total surface built (f²)	398053
Structural category	3D Modular elements all-timber
Podium	None
Core	None
Floor slabs	Box elements - Timber frame
Program	Hotel
External Cladding	Wood
Indoor elements exposed	All the surfaces
Building volume	Pitched roof

CONTEXTUAL DATA

Type of Commission	Direct
Influence	Private
Motivations	Building erection speed
Architect	n/a
Engineer	n/a
Timber Engineer	n/a
General Contractor	Tecno Fast, CL
Timber Contractor	Grupo ASAP, CL
Timber Supplier:	
Structural Elements	Lamitec Chile - Voipir Chile, CL - Hasslacher Nordica Timber, AT
Floor Elements	UFP Camfor, US - CMPC Chile, CL
Client	Anglo American, INT

SOURCE OF IMAGES

Tecnofast