Innovation processes in energy - efficient timber construction in Austria

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Abstract

Increased ecological consciousness and stricter building standards regarding energy efficiency are a motivation for innovations in the construction sector and offer great market potential for timber construction. The aim of this thesis is the analysis of the innovation system and in particular the innovation process in the energy efficient timber construction sector.
Therefor two innovative timber construction projects built between 2006 and 2012 are analysed to identify main actors and their role, the cooperation and interaction process as well as fostering and impeding factors. Additional questions regarding future trends and needs for action are also examined. The investigated cases were selected based on database research and expert interviews, one for the category "public buildings", one "commercial building".
As leading actors mainly the architects and the building promoters are identified as system integrators and driving force, but pro - active information exchange with public and private actors is crucial. Beside common fostering factors such as regional cooperation models, tradition and experience with the building material timber as well as the further development of a more ecologically construction process, in the commercial case study open up new markets and anticipated profit were mentioned as fostering factors as well. The most impeding factors are neither a lack of technological possibilities, nor public regulations were most impeding factors, but rather a lack of positive image as well as a lack of experience and knowledge concerning the construction material timber. Main trends are energy efficient buildings, the application of life cycle analysis, the improvement of prefabrication and multi-storey buildings. Need for action is seen in the elimination of prejudices towards timber, in the attitude towards cooperation and in increased inclusion of pubic adminnistration.

Wachsendes ökologisches Bewusstsein sowie strengere Baustandards hinsichtlich Energieeffizienz geben Motivation für Innovationen im Bausektor und bieten erhöhte Marktchancen für den Holzbau. Das Ziel der Diplomarbeit ist die Analyse des Innovationssystems und insbesondere des Innovationsprozesses im energieeffizienten Holzbausektor mit Hilfe von Fallstudien an Holzbauten der Jahre 2006 bis 2012. Dabei wird der Frage nach den wesentlichen Akteuren und deren Rolle, dem Kooperations- und Interaktionsprozess sowie den förderlichen und hinderlichen Faktoren nachgegangen. Zukünftige Entwicklungen und Handlungsbedarf für den Holzbau werden ebenfalls analysiert. Die untersuchten Fallbeispiele wurden zuvor mittels Datenbankrecherche und Experteninterviews aus den Kategorien "Öffentlicher Bau" und "Gewerbebau" ermittelt.
Hauptakteure und treibende Kraft sind hauptsächlich Architekt und Bauträger, jedoch ist der pro aktive Informationsaustausch mit öffentlichen und privaten Akteuren entscheidend. Neben Faktoren wie regionalen Kooperationsmodellen, Tradition und Erfahrung mit Holz als Baumaterial und der Weiterentwicklung umweltbewusster Bauprozesse, gelten im Falle des Gewerbebaus zusätzlich der erwartete Gewinn sowie die Erschließung neuer Absatzmärkte als Motivationsfaktoren. Weder die technische Realisierung noch öffentliche Regelungen wurden als hinderlich empfunden, sondern eher mangelndes Image, Erfahrung und Wissen hinsichtlich dem Baumaterial Holz. Als wichtige Entwicklungen gelten der energieeffiziente Bau, die Lebenszyklusanalyse, die Verbesserung der Vorfertigung und die Fertigung von Hochhäusern aus Holz. Handlungsbedarf wird in der verstärkten Kooperation, insbesondere mit den Behörden und in der Beseitigung von Vorurteilen gesehen.

Table of Contents

LIST OF FIGURES 6

LIST OF TABLES 6

LIST OF ABBREVIATIONS 7

1. INTRODUCTION / QUESTION 10

2. THEORY 14

2.1. INNOVATION 14
2.1.1. DEFINITION OF INNOVATION 14
2.1.2. CLASSIFICATION OF INNOVATION 15
2.2. THEORETICAL MODELS FOR ANALYSING INNOVATION PROCESSES 17
2.2.1. WHAT INNOVATION IS NOT: THE LINEAR MODEL 17
2.2.2. THE SYSTEMS OF INNOVATION 18
2.2.3. INNOVATION IN THE CONSTRUCTION SECTOR 23
2.3. ACTORS AND INSTITUTIONS IN THE ENERGY EFFICIENT TIMBER CONSTRUCTION SECTOR IN AUSTRIA 28
2.3.1. PRIVATE ACTORS 28
2.3.2. PUBLIC ACTORS 28
2.3.3. RELEVANT INTEREST GROUPS FOR THE TIMBER CONSTRUCTION SECTOR 31
2.3.4. RESEARCH AND DEVELOPMENT INSTITUTIONS, VOCATIONAL EDUCATION AND TRAINING 40
2.3.5. RELEVANT CLUSTERS AND NETWORKS 51
2.3.6. RELEVANT POLICIES 54
2.3.7. ENERGY EFFICIENT BUILDING STANDARDS 57

3. METHODOLOGY 61

3.1. CASE STUDY SELECTION 61
3.1.1. LITERATURE AND DATABASE RESEARCH 62
3.1.2. EXPERT INTERVIEWS FOR DETERMINATION OF THE CASE STUDIES 65
3.2. CASE STUDY ANALYSIS 67
3.2.1. INTERVIEWING THE MAIN ACTORS OF THE INNOVATIVE CASE STUDIES 69

4. FINDINGS 72

4.1. DETERMINATION OF THE CASE STUDIES 72
4.1.1. LITERATURE AND DATABASE RESEARCH 72
4.1.2.EXPERT INTERVIEWS FOR DETERMINATION OF CASE STUDIES 75
4.2. CASE STUDY 1: COMMUNITY CENTRE ST.GEROLD 77
4.2.1. DEVELOPMENT STAGES ST.GEROLD 77
4.2.2. THE INNOVATIVE ASPECTS 81
4.2.3. THE CONSTRUCTION 82
4.2.4. INVOLVED ACTORS AND THEIR ROLES 87
4.2.5. COOPERATION, INTERACTION AND INFORMATION FLOW 90
4.2.6. CONFLICT MANAGEMENT AND PROBLEM SOLUTION 92
4.2.7. FOSTERING AND IMPEDING FACTORS 92
4.2.8. EVALUATION OF CASE STUDY 1 AND TRANSFERABILITY 94
4.3. CASE STUDY 2: LIFE CYCLE TOWER ONE (LCT ONE) 97
4.3.1. DEVELOPMENT STAGES OF THE LIFE CYCLE TOWER ONE 97
4.3.2. THE INNOVATIVE ASPECTS 100

4.3.3. THE CONSTRUCTION 102
4.3.4. INVOLVED ACTORS AND THEIR ROLE 106
4.3.5. COOPERATION, INTERACTION AND INFORMATION FLOW 110
4.3.6. CONFLICT MANAGEMENT AND PROBLEM SOLUTION 111
4.3.7. FOSTERING AND IMPEDING FACTORS 113
4.3.8. EVALUATION OF CASE STUDY 2 AND TRANSFERABILITY 116
4.4. FINDINGS OF THE CASE STUDY ANALYSES 119
4.4.1. INVOLVED ACTORS AND THEIR ROLE 119
4.4.2. COOPERATION, INTERACTION AND INFORMATION FLOW 120
4.4.3. CONFLICT MANAGEMENT AND PROBLEM SOLUTION 121
4.4.4. FOSTERING AND IMPEDING FACTORS 122
4.4.5. NEED FOR ACTION 127
4.4.6. TRENDS AND CHALLENGES FOR THE TIMBER CONSTRUCTION 128

5. SUMMARY AND OUTLOOK 132

LIST OF LITERATURE 141

List of figures

Figure 1: Types of innovation	16
Figure 2: A globalized interactive complex systems industry	24
Figure 3: 4 storey perspective, south-west side, St.Gerold	83
Figure 4: Main entrance and newly created village square, east side	83
Figure 5: Floorplan	84
Figure 6: Section	85
Figure 7: Local authority	86
Figure 8: Kindergarten	86
Figure 9: Staircase	87
Figure 10: LCT One, front view	100
Figure 11: Section	100
Figure 12: Entrance area	102
Figure 13: Visible load bearing timber components	103
Figure 14: Timber concrete hybrid slab	103
Figure 15: Complex information flow during the innovation process	120

List of tables

Table 1: Basic principles for the construction of Passive Houses	59
Table 2: List of institutions contacted for the expert interviews	66
Table 3: List of interviewed actors for the first case study	69
Table 4: List of interviewed actors for the second case study	69
Table 5: Results of the architectural databank “nextroom”	72
Table 6: Results of the “klima:aktiv” database	73
Table 7: Results of the state award of architecture and sustainability	74
Table 8: Number of timber construction projects from database research	74
Table 9: Involved actors in the varying construction phases (St.Gerold)	88
Table 10: Involved actors in the varying construction phases (LCT One)	106
Table 11: Fostering factors	123
Table 12: Impeding factors	125

List of abbreviations

AEA	Österreichische Energieagentur (Austrian Energy Agency
AHS	Allgemeinbildende Höhere Schule (Grammar school)
bAIK	Bundeskammer der Architekten und Ingenieurkonsulenten (Austrian Federal Chamber of Archictects and Engineers)
BDB	Baudatenbank (Construction database)
BHS	Berufsbildende Höhere Schule (Vocational School with higher Education Entrance Qualification)
BKA	Bundeskanzleramt (Federal Chancellery)
BM:LFUW	Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wassermanagement (Federal Ministry of Agriculture, Forestry, Environment and Water Management)
BM:WF	Bundesministerium für Wissenschaft und Forschung (Federal Ministry of Sience and Research)
BM:WFJ	Bundesministerium für Wirtschaft, Familie und Jugend (The Federal Ministry of Economy, Family and Youth)
BM:VIT	Bundesministerium für Verkehr, Innovation und Technologie (Federal Ministry of Transport, Innovation and Technology)
BOKU	Universität für Bodenkultur (University of Natural Resources and Life Sciences)
BSH	Brettschichtholz (Glued Laminated Timber)
BWF	Bundesforschungszentrum für Wald (Federal Research Center Wood)
B-VG	Bundesverfassungsgesetz (Federal Constitutional Law)
CEIB	Zentralverband der europäischen Holzindustrie (European Confederation of Woodworking Industries
CO2	Kohlendioxid (carbon dioxide)
COMET	Kompetenzzentrenprogramm (Competence Centers for Excellent Technologies)
CREE	Creative Resource and Energy Efficieny
EPBD	Gebäuderichtlinie über die Gesamtenergieeffizienz von Gebäuden (Energy Performance of Building Directive)
FFG	Österreichische Forschungsförderungsgesellschaft (The Austrian Research Promotion Agency)

FGW	Forschungsgesellschaft für Wohnen, Bauen und Planen (Living, Building and Planning Research Association)
FH	Fachhochschule (College)
FHP	Kooperationsplattform Wald-Holz_Papier (Cooperation Platform Forest-Wood-Paper)
GBH	Gewerkschaft Bau-Holz (Union of Construction and Woodworkers)
Ha	Hektor (Hectare)
HIZ	Holzinnovationszentrum Zeltweg (Wood Innovation Center)
HFA	Holzforschung Austria (Wood Research)
HTL	Höhere Technische Lehranstalt (Technical School)
IBO	Österreichisches Institut für Baubiologie und –ökologie (Austrian Institute for Building Biology and Ecology)
IBS	Institut für Brandschutztechnik und Sicherheitsforschung (Institute for Fire Protection and Safety Research)
InFER	Institut für Wald-, Umwelt- und Ressourcenpolitik (Institute of Forest, Environmental, and Natural Ressource Policy)
IZM	Illwerke Zentrum Montafon
kWh/m2a	Kilowattstunden pro Quadratmeter und Jahr (Kilowatt Hour per Unit area and year)
LCT	Life Cycle Tower
LCT One	Life Cycle Tower One
NSI	nationales Innovationssystem (National System of Innovation)
OECD	Organisation für wirtschaftliche Zusammenarbeit und Entwicklung (Organisation for Economic Co-operation and Development)
OEFV	Österreichischer Fertighausverband (The Austrian Association of Prefabricated Housing)
OEGB	Österreichische Gewerkschaftsbund (Austrian Trade Union Federation)
OEGH	Österreichische Gesellschaft für Holzforschung (Austrian Society for Wood Research)
OEGNB	Österreichische Gesellschaft für nachhaltiges Bauen (Austrian Sustainable Building Council)
OEGUT	Österreichische Gesellschaft für Umwelt und Technik (Austrian Society for Environment and Technology)
OEIAV	Österreichischer Ingenieur,- und Architekten Verein (Austrian Society for Engineers and Architects)

OELV	Österreichischer Holzleimbauverband (Austrian Wood Glue Construction Association)
OIB	Österreichisches Institut für Bautechnik (Austrian Institute of Construction Engineering)
PHPP	Passivhausprojektierungspaket (Passive House Planning Package)
R&D	Forschung & Entwicklung (Research & Development)
REI (F)	Feuerwiderstandsklasse (Fire –resistance Rating)
RSI	regionales Innovationssystem(Regional System of Innovation)
SI	Innovationssystem (System of Innovation)
SME	Klein-, und Mittelbetriebe (Small and Medium sized Enterprises)
SSI	Sektorales Innovationssystem (Sectoral System of Innovation)
TU Graz	Technische Universiät Graz (Graz University of Technology)
TU Wien	Technische Universiät Wien (Vienna University of Technology)
Vfm	Vorratsfestmeter (Solid Cubic Meters)
WKO	Wirtschaftskammer Österreich (The Austrian Federal Chamber)

1. Introduction / question

The master thesis intends to analyse the innovation system and innovation processes in the energy-efficient timber construction sector in Austria, because both, timber construction sector and innovation studies have strongly evolved during the last decade.

For millennia, timber construction was the prevailing method of construction in Europe. Wood together with stone and clay is humanity´s oldest and most basic building material. Tried and tested over many thousands of years of use this renewable material still offers unique and fascinating qualities. It is only since the 19^{th} century, through the development of new material (steel and concrete), that it has been pushed to the margins. However, its significance is renewed.

According to the Bundesforschungszentrum für Wald (BFW) and its accomplished "österreichische Waldinventur 2007/09" (Austrian forest inventory), 47,6% of Austria's surface area is forested (4 Mio. ha). Austria commands wood reserves (wood in forests) of 1135 Mio. solid cubic meters (Vorratsfestmeter) (Vfm) and the annual increment amounts to 30,4 Mio. cubic meters of wood in harvested forests. Three quarters of these increment is used (25,9 Mio. cubic meters), the rest remains in the forests and results in increased forest area (BWF 2013).
Consequently, Austria is one of the most tree-covered countries in Europe and wood reserves increase continually (proHolz 2013).

Wood is a natural, extremely versatile material in both appearance and in its potential uses (Wegener 2012,10ff).
In terms of sustainability and environmental friendliness, timber is superior to most other common building materials. During the production of steel and concrete, today´s particularly important materials, much energy and CO2 must be expended whereas timber-supplying trees consume CO2 during growth. Accordingly, a building constructed of timber must be understood as a form of CO2 storage. Even at the end of its life cycle, the energy bound in timber is not lost. Liberated CO2 goes back into natural circulation. Timber use is active climate protection (König 2012, 16ff).
However, timber constructions have still a poor market share compared to other construction materials and other countries (proHolz 2013).

In light of escalating climate problems and in times where energy efficiency and renewable resources are from great relevance, timber constructions can contribute substantially to a more sustainable lifestyle in society (König 2012, Kuittinen et al. 2013, proHolz 2013,).

Huge varieties of innovation based on constructional engineering, computerised calculation and assembly methods have achieved important improvements in fire prevention, noise protection and enable completely new design possibilities.
Changed framework conditions in the timber construction sector such as new construction regulations that foster constructions with energy-efficient, regional and sustainable materials, make the topic of great significance (Kaufmann and Nerdinger 2012).

Timber represents itself as an all-rounder in the construction sector and has the ability to combine architectural design with ecodesign as no other material.
Ecological buildings and natural materials are gaining ground, in the sense of environmental protection and indoor environmental quality.
These are the main arguments for analysing the innovation processes in the timber construction sector.

The main questions in the analysis of the innovation process in the energy efficient timber construction are:

- What are the most important fostering and impeding factors in the innovation process during a timber construction project?
- Who are the main actors, what are their roles and how is their interaction with each other?
- Which trends and challenges arise for timber constructions in future?

To gain the ability for answering these questions, this thesis conducts a detailed examination of the innovation processes in two case studies in the categories “public buildings” and “commercial buildings” built in Austria between 2006 and 2012.
It is used a similar procedure of database research and expert interviews for analysing the case studies as Schwarz (2009) used in his thesis about innovations in timber constructions. His cases belong to the categories “ public buildings” and “residential buildings” built in Austria between 1995-2005 (Schwarz 2009).

The detailed description of successful and innovative timber construction projects is a possibility to enhance the positive image of timber construction development (Nord et al. 2011, 205). This thesis intends to demonstrate innovative projects in Austria for a more sustainable construction sector. Further promotion of the principle of sustainability is seen as useful to offer policy makers and building promoters ecological possibilities and thoughts to take with them.

This thesis is done at the Institute of Forest, Environmental, and Natural Resource Policy (InFER) within the project "ECO2-Effizientes Bauen mit Holz" (ECO2-efficient construction with wood) which aims to get an understanding of carbon-efficiency along the entire life cycle of a building.
InFER has a focus on political science research on processes, instruments and institutions, sustainable development policies and is concerned with forest policy issues and innovation in the forest-wood chain. The master thesis is written in cooperation with the Lincoln University, New Zealand, as part of the international master study "Natural Resources Management and Ecological Engineering".

The first, theoretical part of the thesis has the focus on innovation and the innovation processes in innovation systems. Based on the specialisation on the timber construction sector, the sectoral system of innovation is illustrated in detail. Terms are defined and classifications as well as characteristics are described. In addition, this part gives an overview of the most essential actors and institutions in the energy efficient timber construction sector in Austria. Aims and tasks of private- and public actors, relevant representation of interests, research and development institutions and clusters are described. Further, relevant policies and energy efficient building standards are described.

The second, empirical part of the thesis delineates the methodical approach, offers a detailed description of the two case studies and represents and discusses the findings.
Interviews with experts from relevant, national research institutes regarding timber constructions have been done to be in the ability to determine as innovative and energy efficient case studies as possible.
The main part of the thesis deals with a detailed analysis of the prior determined case studies. Those are separately approached and analysed in regard to their actors and their role, interaction and cooperation, fostering and impeding factors as

well as trends and challenges. According to the leading questions the findings of each case study are described together.

The thesis ends with a discussion of the findings and a summery.

2. Theory

2.1. Innovation

2.1.1. Definition of Innovation

In literature, the term innovation is defined in various ways and no consensus on the definition exists due to complexity and varying areas of application.
In general, innovation is considered to be the successful introduction of a novelty on the market but does not state anything about the success (Rametsteiner 2000, Lundvall 1992 cited in Rametsteiner and Kubeczko 2003, 15).

Seen from an economic and business perspective, modern innovation research is mostly based on the work of Josef Schumpeter who laid the focus on the role of firms and entrepreneurs as the driving force behind economic growth (Rametsteiner and Kubeczko 2003,15, Weiss et al. 2011,11). Although the term is associated commonly with technological innovation, nowadays there is an increased research interest in non-technological, especially institutional innovations as well (Rametsteiner E. and Kubeczko K. 2003, 15, Weiss G. 2011, 11).

An essential differentiation is made between invention, the first appearance of an idea, and innovation, the first try to implement an idea into practice. There exists often a substantial time lapse between invention and innovation due to different requirements for development of ideas and implementation of them or some of the conditions for commercialization may be lacking (Fagerberg 2005,4 et seqq.). Fagerberg (2005, 5) refers to innovation as a continuous and lengthy process, involving many interrelated inventions and innovations to reach the innovation stage. Another difference is the fact that inventions can be developed anywhere (like research institutes), while the commercialization take place mainly in firms (Fagerberg 2005, 5). That a firm is in the position to turn an invention into an innovation, it should be able to combine various types of knowledge, skills, capabilities and resources.

In this thesis, the term innovation is defined broadly and is generally used from an economic and business perspective where the focus is on innovations on the market.

The OECD defines innovation as “the implementation of a new or significantly improved product (good or service) or process, a new marketing method, or a new organizational method in business practices, workplace organisation or external relations “ (OECD 2005, 47)

It follows the enlarged definition of Weiss et al. (2010a), which adds to the OECD categories also policy and institutional innovations.

2.1.2. Classification of innovation

Edquist (2005, 182) classifies innovations into “product as well as process innovations. Product innovations are new-or better- material goods as well as new intangible services. Process innovations are new ways of producing goods and services. They may be technological or organizational.”

In a slightly different form, the OECD´s classification of innovation distinguishes the following four types of innovation:

- product innovation: the introduction of a good or service that is new or significantly improved
- process innovation: the implementation of a new or significantly improved production or delivery method
- marketing innovation: the implementation of a new marketing method involving significant changes in product design, packaging, product placement, product promotion or pricing
- organisational innovation: the implementation of a new organisational method in the firm´s business practices, workplace organisation or external relations (OECD 2005, 48 et seqq.)

From an economic perspective, the focus has been on the two first of these (Fagerberg 2005, 7). However, Weiss (2010a) added additionally the category of institutional innovations; both to enlarge the understanding of innovation as well as to include further innovations that need institutional or policy changes.

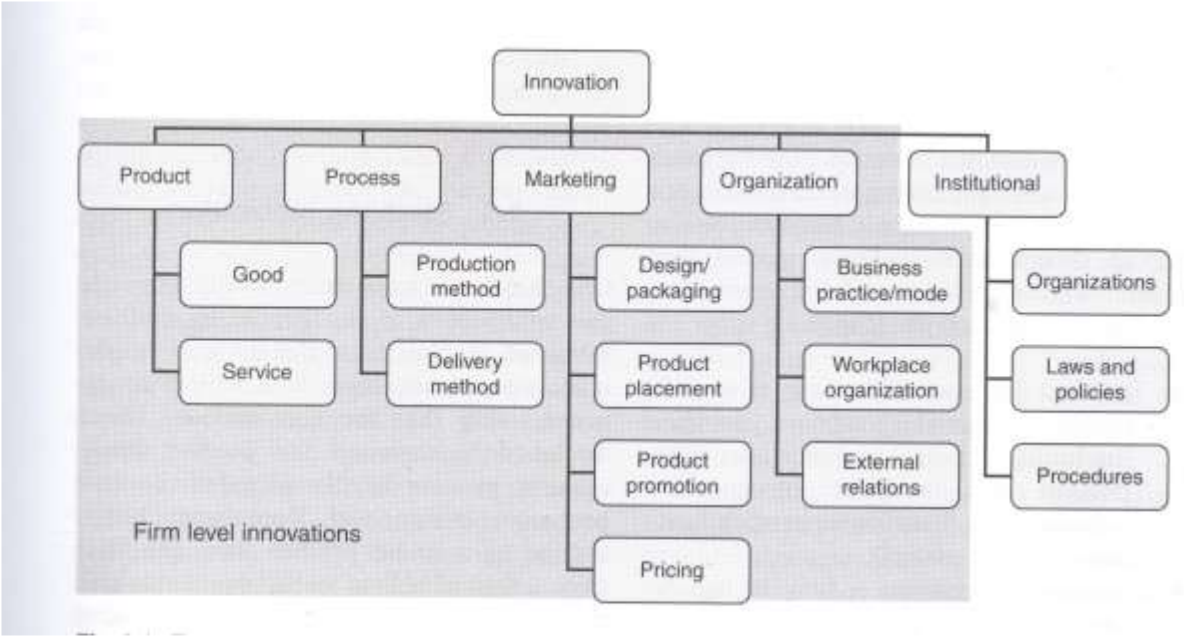

Figure 1: Types of innovation (Weiss et al. 2010a, modified from OECD 2005 cited Weiss 2011, 11)

In real life, the types of innovation often overlap, thus the market introduction of new products often requires changes in other fields as well. According to Weiss (2011, 12) many improvements/innovations cannot be realised by market actors alone but rather depend on changes in the institutional environment (such as regulations or incentives).

Another primary feature is the degree of novelty. From this perspective there is a distinction whether an innovation shows only minor (incremental) changes compared to solutions already known, or profound (radical) changes (Rametsteiner and Kubeczko 2003, 15). Incremental changes are considered to be continuous improvements whereas radical changes are the introduction of a totally new innovation. The more radical an innovation is, the greater the possibility that it may require social, political or infrastructural change (Fagerberg 2005, 7 et seqq.). However, incremental innovations have to be considered as equally important because many step-by step or incremental changes may have great impact on economic benefits (Fagerberg 2005, 8, Weiss 2011, 12).

In addition, a commonly used distinction is that between innovations new to the entire market, new to the sector or only new to the firm. From a macro-economic perspective an innovation that is new to a firm but not to the whole market is called innovation diffusion (Rametsteiner and Kubeczko 2003, 15, OECD 2005, 57).

2.2. Theoretical Models for analysing innovation processes

In innovation literature, there exists a wide range of varying theoretical and conceptual approaches relevant for the analysis of innovation processes that changed their character, research focus or emphases over time (Fagerberg 2005, 4 et seqq., Weiss 2011). The field of innovation studies has grown rapidly as did the number of scholars in this area in recent years. Research on innovation has now developed into a much broader and more international community with a strong orientation towards cross disciplinary (Fagerberg 2005, 3). These facts illustrate the need for innovation to be studied from different perspectives (Fagerberg 2005, 20, Weiss 2011, 11)

2.2.1. What innovation is not: the Linear Model

From the linear perspective, innovation (predominantly technological novelties) is considered to undergo a linear process starting from scientific research via experimental development of new technology to innovative, marketable products (Hirsch-Kreinsen and Jacobson 2008, 25)
It is based on the assumption that innovation goes through a well-defined set of stages, which is not true (Fagerberg 2005, 8 et seqq).

Based on the fact that it paints a far too simple picture of the innovation process, scholars note that the linear model is not an appropriate approach to represent the innovation process. A problem is the non-consideration of complex linkages of diverse actors in space and time and potentially occurring feedback - loops between the different stages. Another problem of the linear model is the implication of a chain of causation that is not true of most innovations (Fagerberg 2005, 8 et seqq.). Further innovation is not necessarily based on scientific research or even on scientific knowledge (Hirsch-Kreinsen and Jacobson 2008, 25).

According to Hirsch-Kreisen and Jacobson (2008, 25) the linear model of innovation is something of a “conceptual zombie”. As a consequence, it should be of little relevance to theoretical and empirical research on innovation processes today.

During the early 1990s the systemic approach superseded the linear model.

It is not longer the passive, adaptive process but rather a process of interchange and transformations, a distributed process (Rametsteiner and Kubeczko 2003, 14).

2.2.2. The Systems of Innovation

A central finding in innovation literature is that in the majority of cases, innovation activities of firms depend on external sources. The innovation system approach reflects this rise of systemic approaches where innovation is the result of complex interaction between varying actors and institutions (Edquist 2005,181 et seqq., Fagerberg 2005, 4 et seqq., Malerba 2004, 7 et seqq.). Although firms and their style of producing and innovating are still focus of interest, the analysis of the wider framework in which these activities are embedded are equally important.
These external sources of knowledge may be other firms, private and/or public research institutes, universities or other regional, national or international institutions and/or experts. As a natural consequence, in the systemic innovation research, increasingly connections, feedbacks, networks and institutional structures as well as legal requirements, regulations or quality requirements are analysed (Edquist 2005, 181 et seqq.).
Edquist (2005, 182) refers to system of innovation (SI) as the “determinants of innovation processes” that delineates “all important economic, social, political, organizational, institutional and other factors that influence the development, diffusion and use of innovations”.

2.2.2.1. Varying System of Innovation approaches

According to Fagerberg (2005, 12 et seqq.) there exist two main approaches in the innovation-systems literature.

The first important approach describes systems based on technological, industrial or sectoral characteristics, but even so other relevant factors such as institutions (laws, rules, tradition, etc.), the political process, public research institutes (universities), professional qualifications and financial institutions have to be considered as well. This sectoral system approach lays the focus on doing research on the technological dynamics of innovation, its varying phases and how this process affects or is under the influence of social, institutional and economic parameters.

The second approach distinguishes between systems on the basis of national and regional borders and concentrates on the spatial level. As a result, there is talk of national systems of innovation (NSI) and regional systems of innovation (RSI). This approach focuses mainly on political and administrative factors that affect the system (Fagerberg 2005, 12 et seqq.).

In other words the point of view has expanded from the national approach towards sectoral research and regional and international systems during the course of recent years. In this way, three system innovation approaches may be distinguished:

- National Innovation Systems: a research approach that is geared to national economies with national boundaries and mainly analyses actors on a national level, their activities and their interaction
- Regional Innovation Systems: a research approach similar to the national approach except that concentrated on a defined region.
- Sectoral Innovation Systems: a research approach that analyses the system of actors from a specific sector as well as their activities and interaction. (Rametsteiner and Kubeczko 2003, 16, Weiss 2011)

The three approaches-national, regional and sectoral-are varying variants of the systems of innovation approach and exist and may be applied in parallel (Edquist 2005, 184, Weiss 2011).
According to Malerba (2004, 10) a sectoral system of innovation perspective complements other concepts such as national, regional/local or technological innovation systems. This thesis focuses mainly on sectoral systems of innovation (timber construction sector), but in addition addresses national (Austria) and regional systems (Vorarlberg) of innovation to a certain extent.

2.2.2.2. The main components of innovation systems

According to Edquist (2005, 188) the main components in SIs are organisations, institutions and the relations among these two.

Organisations
"Organisations are formal structures that are consciously created and have an explicit purpose" (Edquist 2005, 182). Edquist (2005, 182) refers to organisation as "players or actors". Thus, organisations are defined as the actors of the innovation

system. Examples of organisations in SIs are other firms, universities, venture capital organisations, public agencies, etc..

Institutions

"Institutions are sets of common habits, norms, routines, established practices, rules or laws that regulate the relations and interactions between individuals, groups and organisations". Edquist (2005, 182) refers to institutions as "the rules of the game". Possible institutions are for instance patent laws, building laws but even so rules and norms affecting the relations between varying actors.

However, the specific constitution of both, organisations and institutions, differ from system to system and among national SIs (Edquist, 2005, 188, Malerba 2004, 5 et seqq.).

Relations and interaction between the components of SIs

On the basis of the innovation system approach outlined above, firms and other organisations do not perform activities (innovate) in isolation but rather depend on interaction with its institutional environment that determines incentives and/or obstacles influencing these activities. Organisations are strongly shaped and affected by institutions and their set of rules such as the legal system, norms, standards, etc. To be in the ability to understand the innovation process it is from Edquist´s (2005) point of view essential to delineate the relations and interaction between components and their activities.

In most cases the relations are very complex and characterized by reciprocity and feedback mechanisms in several loops with the result that scientific knowledge about these complex relations are limited and measurement difficult.

Thus, not only the main components (institutions and organisations), but also the relations between them are interactive and influence the innovation process (Edquist, 2005, 184 et seqq.).

"Systems are a set of activities (or actors) that are interlinked and this leads naturally to a focus on the working of the linkages of the system" (Fagerberg 2005,13). However, it should not be left behind that on the one hand the structure of a system may facilitate pattern of interaction or outcome and supports certain types of activities but on the other may constrain unperceived opportunities of development. "The more open a system is for impulses from outside, the less the chance of being locked out from promising new paths of development that emerge outside the system" (Fagerberg 2005, 13).

In this thesis the innovation system approach is seen as the appropriate theoretical approach because this perspective is useful in understanding and analysing the innovation processes of both, organisations and institutions as well as interaction of these.

2.2.2.3. Sectoral systems of innovaton (SSI)

The analysis of innovation in sectors is based on the concept of systems of innovations explained above.
Related to the framework of Malerba´s (2004) systemic approach of innovation, this thesis places the sectoral system perspective at the center of focus. It is a useful tool for a descriptive analysis of the innovation process in sectors (in this case the timber construction sector) and for a better understanding of the actors and their interaction as well for the recognition of the factors affecting innovation.

According to Malerba (2004,10) it is composed of "a set of actors carrying out activities and market and non-market interactions for the creation, production and sale of sectoral products.
Malerba (2004,16) refers to a sector as " a set of activities unified by some linked product groups for a given or emerging demand and characterized by a common knowledge base".
In a sectoral system innovation (SSI) perspective, firms have commonalities and at the same time are different. According to Malerba (2004) firms are active actors that shape their technological and market environments.

The concept of the SSI framework used here deviates from the traditional concept of sectors used in industrial economics. It does not exclusively concentrate on firms but rather is characterised by additional examination of non-market as well as on market interactions, institutions and the process of transformation of the system (sectoral boundaries are not considered as given and static).
Boundaries of sectors should include interdependencies and links among related industries. As a result these boundaries are not fixed but change over time.
Thus, a sectoral system undergoes processes of change and transformation through the coevolution of its various elements (Malerba 2004, 10 et seqq.).

Malerba (2004, 3 et seqq.) identifies the following three main factors

1. Knowledge and technologies
2. Actors and networks
3. Institutions

affecting innovation in a sector.

First, every sector is distinguished by a specific knowledge base, technologies and inputs, which shape the nature, boundaries and organizations of sectors.
Second, a sector consists of various actors that are organizations or individuals (such as consumers, entrepreneurs and scientists), which are connected in various ways through market and non-market relationships.
Actors are characterized by specific learning processes, competencies, beliefs, objectives, structures and behaviours and interact through process of communication, exchange, cooperation, competition and command.
The type and structure of relationships differ from sector to sector due to varying knowledge base, learning processes, basic technologies, etc..
Third, all activities of the varying actors and their interactions are shaped by institutions, which include norms, routines, common habits, established practices, rules, laws, standards, etc.. Institutions may range from more binding to less binding and from formal to informal, are national (such as patent system) or specific to sectoral systems (such as sectoral labor markets).

In addition, Malerba (2004,3) identifies demand as a decisive factor of a sectoral system, both in affecting innovation and during the emergence and transformation of sectoral systems. Changes in demand conditions influence sectoral differences in firm´s competencies, behaviour and organization.

In other words, innovations take place in quite different sectoral environments, in terms of sources, actors and institutions. The organizational rules and institutional arrangements vary with the knowledge and technological intensity of the sector.

One note has to be advanced here. The appropriate level of analysis in terms of actors and functions depends on the specific research goal. The same holds for the large or narrow sectoral boundaries, thus the level of aggregation depends on the goal of the analysis as well (Malerba 2004).

In this thesis, sectors have been defined broadly as construction sector and timber construction sector.

2.2.3. Innovation in the construction sector

In the past the construction sector was considered to be traditional as well as conservative with low innovation capacities (Czerny et al. 2010). Reasons for that negative innovation image are certain characteristics of the industry as well as unsuitable data from traditional indicators for measuring innovation. In the construction sector innovations are predominantly process oriented, thus not covered by traditional innovation indicators such as research expenses (Czerny et al. 2010).

The construction sector as a whole is an important economic factor for most European countries. Standards and norms have developed over time due to the long history of this sector. Based on these facts, state and policy makers have seen the importance to innovate policies towards increased innovation that simultaneously fit together with general conditions of the industry (Nord et al. 2011).

Based on complex linkages but even so differences, it is important to differentiate between different construction sectors such as project planning and engineering services (planners, architects), building supply and production of construction material (producers, trade), processing industry (construction ancillary trade, construction industry), building promoter and residential trade and industry.
Further, the construction sector as a whole strongly depends on external sources, technology transfer of other companies and upstream industry and represents with the variety of participating companies a complex system (Czerny et al. 2010, Nord et al. 2011, Winch 1998).
Due to the complex and interlinked cooperation activities within the varying branches there is no exact separation feasible, which makes it hardly possible to analyze innovation activities detached (Czerny et al. 2010).

Like every other industry, the construction sector has to fulfil various changes and has to solve diverse challenges. While in previous times the focus was on optimization of cost and quality, nowadays a holistic view as well as enhancement of efficiency, especially energy efficiency and consideration of the entire life cycle of a building is getting more important.

That implies a new paradigm for the construction sector, which is based on the conventional cornerstones (cost-, time- and quality optimisation), environmental conditions (resource-, emissions-, energy-, waste optimisation) as well as realization of requirement of accommodation and customer wishes (Czerny et al. 2010).

From the systemic perspective of innovation, thus the innovation process is influenced by various environmental factors outside a firm, Winch (1998) describes the construction sector as a “complex system industry” and the constructed product as a “complex product system”.
According to Winch´s model, actors from the superstructure level (clients, regulators and professional institutions) are influential and fostering regarding innovation. Further, this group of actors demand innovation from actors of the infrastructure level (trade contractors, specialist consultants and component suppliers). The role of an interface between these two subsystems represents the systems integrators (principal architect/engineer and principal contractor), which mediate in regard to matching the client needs and regulatory requirements (Nord et al. 2011, Winch 1998).

In Figure 2 the interactive complex systems industry by Nord et al. 20011 modified from Winch 1998, is illustrated.

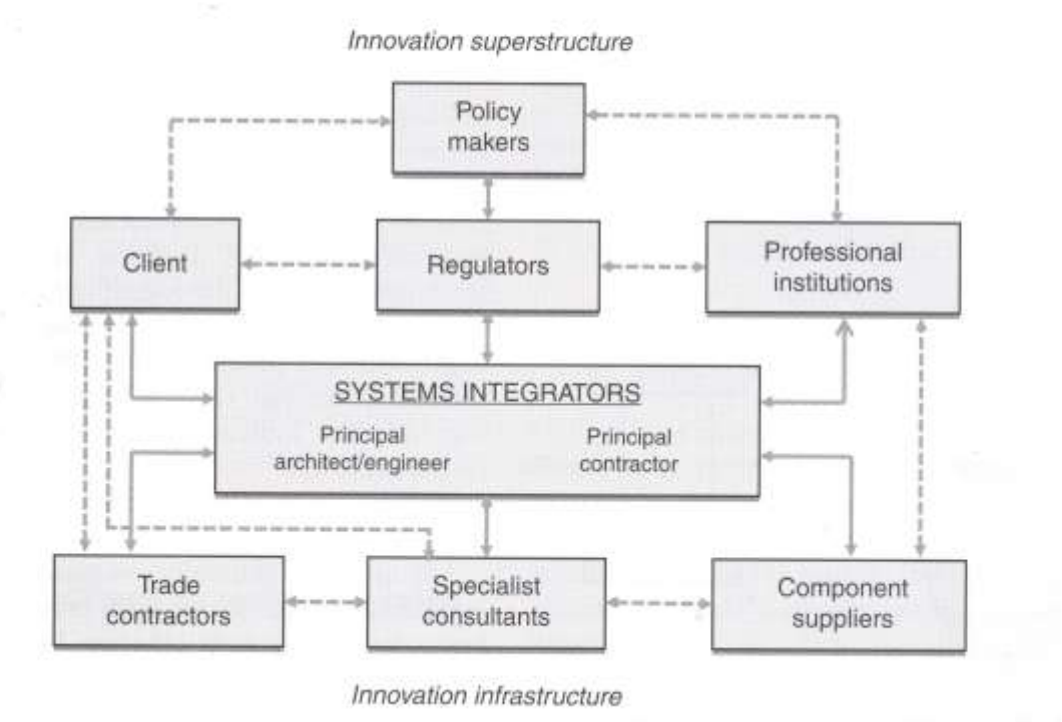

Figure 2: A globalized interactive complex systems industry by Nord et al. 2011, 209 (modified from Winch, 1998)

Seen from an international perspective, Nord et al. (2011) modified the implicitly national perspective of the Winch model in terms of a separation of the regulatory actors into two actor categories (policy makers on national and transnational level that define laws and regulators that interpret such laws into e.g. building codes) as well as a more interactive structure. Further modifications are the inclusion of interactions between actors at the innovation superstructure level as well as possible interactions of actors at the innovation infrastructure and superstructure levels, in which the system integrator is not directly involved. To denote these interactions, such lines are replaced with interconnecting exchanges (Nord et al. 2011, 208). According to Winch (1998) the construction sector is lively source of new ideas. The study of Czerny (2010) as well as other literature (Nord et al. 2011; Tykkä et al. 2009) show that the construction sector has very well a strong innovation strength that is reflected mainly in the productivity.

Innovation in timber construction

Like the construction sector in general, the timber construction industry is known for its conservatism and low innovation rates as well (Tykkä et al. 2009, Winch 1998). However, due to the fact that many European countries implement national development programmes, revise national building regulations and increase marketing effort, the market share of timber frame construction has increased in many European countries, albeit from a low level (Nord et al. 2011, 204).

On the basis of the revised building regulations as well as increased promotion programmes over the last years, the timber constructions industry observed new market opportunities and realized the chance to become an alternative as structural framing material (Nord et al. 2011, 205). Harmonised functional codes are considered to indirectly support timber frame constructions (Tykkä et al. 2009). Another fostering factor for innovation are business opportunities arising from demographic changes, such as increased sustainability, environmental concerns and/or affordable housing. Wood is renowned as a more ecologically sustainable framing material compared to conventional material such as concrete or steel (Nord et al. 2011, Tykkä et al. 2009).

These fostering factors lead to innovations and changes in structure-, and building processes (Nord et al. 2011).

Some countries have introduced policies, which aim to considerably enhance the construction industry effectiveness by radically changing the industry´s processes. Instead of constructing on-site as before, it would be fostering to prefabricate building elements in factory-type environments and then assembled on site. Thus, many innovations build on the possibilities of prefabrication and modularization. Demands for such process innovations are strongly influenced by the automotive industry. Based on such new process concepts and use of wood as load bearing element, timber is considered to be a competitive and interesting construction material and implicitly requires construction firms to innovate (Tykkä et al. 2009).

With reference to the OECD definition of innovation (see theory), timber construction firms have shaped similar types of innovations over the last years: the firms have created product innovations by designing new timber-based building elements, process innovations by designing lean production processes and organisational innovations by establishing off site production and taking responsibility for construction design and sustainability (Tykkä et al. 2009).
With reference to the extension of the OECD (2005) definition by Weiss et al. (2010a) cited Weiss (2011, 11) it is important to mention the institutional innovations by revised building regulations as well because policy changes are decisive for change in the timber construction industry (Nord et al. 2011).

According to some literature, there exist no longer formal policy barriers to the enhanced use of wood in European construction (CEI-Bois 2004; Nord et al. 2011, Tykkä et al. 2009) but many non-regulatory and other influencing barriers still remain (CEI Bois, 2004).

Such non-regulatory barriers are differentiated between

- Institutional barriers: education, training and skills, networking within and between the woodworking and construction industries, planning and life cycle assessment issues
- Technical or practical barriers: durability, lack of timber framed engineering competencies, technical back-up, approvals, lack of interaction with other materials, construction process and availability.

- Economic barriers: costing and pricing, risk, investment by all sectors, insurance policies, lack of common methodology (e.g. in manufacturing), taxes, and supply chain.
- Cultural barrier: poor perception of wood as a suitable material for building and living with wood.

Due to the fact that the timber construction industry was excluded from various market segments before revision of the building regulations, it is, especially in the multi-story construction, a relatively young industry (Nord et al. 2011).
As a result, there are common threads in the perceptions of wood among consumers and building professionals and strong prejudices, especially regarding fire resistance and sound insulation, still remain.

2.3. Actors and institutions in the energy efficient timber construction sector in Austria

Based on the master thesis of Bernhard Schwarz, (2009) the following chapter outlines the most important actors and institutions in the energy efficient timber construction sector in Austria. Tasks, structure, aims and range of responsibilities of the relevant actors are updated, extended and translated into English. Furthermore, relevant policies and building standards are described.

2.3.1. Private Actors

An essential group of private actors is the woodworking industry from trade and industry, including timber construction companies like frame carpenters, prefabricated house producers plus the ancillary industries.
In Austria, the wood working industry had a production volume from 7,64 billion Euros (accounting year 2011) and with 28 606 employees one of the biggest industries and employer in Austria.
The timber industry counts 1489 companies, whereof most of them are small and medium sized enterprises (WKO 2012, 5).

Other important professional groups are planning offices and advisory bureaus from freelance civil engineers to architects. In Austria an increased number of architects and engineers have a focus on resources efficient architecture and timber constructions.
According to the Austrian Federal Chamber of architects and engineers, there exist 3423 executive architects and 2287 engineers in Austria, retrieved 2012. (bAIK 2012).

Further important to mention are private customers as well. In present times customers have certain social, economic and ecological demands and ideas regarding their buildings, working place or private surrounding. Public administration, industry and private customers order explicitly timber constructions due to positive influence on the ecological balance of a building.

2.3.2. Public Actors

2.3.2.1. Relevant Federal Ministries (Relevante Bundesministerien)

The federal government is entrusted with the highest administrative duties of the Republic of Austria in so far as this is not assigned to the Federal President and consists of the Federal Chancellor, the Vice-Chancellor, and the other Federal Ministers (B-VG 2010, Article 69 (1)).
As a collegiate branch of government it executes only those duties, which have been expressly entrusted to it by law. The Austrian governments most important constitutional responsibility is its function to pass bills and resolutions unanimously. The separation of power within the Austrian government is given through 9 Austrian Ministries. Duties and designations of the Federal Ministries are established on the basis of the ministerial law (BKA 2013).

Federal Ministry of Economy, Family and Youth (Bundesministerium für Wirtschaft, Familie und Jugend) (BM:WFJ) is responsible for national affairs regarding the construction sector and the timber construction sector as subdivision. Main function, influencing the building industry directly or indirectly, is the national economic policy with several key elements.
One element for the business sector is the provision of the best possible framework conditions for enterprises as well as offering support for all activities that enhance competiveness and economic growth, like financial support, subsidies, and incentives for apprenticeships.
Another element is the innovation and technology policy to promote investment in research, development and innovation to create appropriate conditions for strengthening Austrian companies. For these purposes, a selected range of programmes, initiatives and networks is available.
Another essential activity realized by the BM:WFJ is the presentation of a variety of state awards with the aim to enhance competiveness and to encourage innovation strength. Especially the state prize for architecture and the state prize for innovation are worthy to mention in the context of innovation in the energy efficient timber construction (BM:WFJ 2013).

Federal Ministry of Agriculture, Forestry, Environment and Water Management (Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wassermanagement) (BM:LFUW) contains 7 departments whereby the department “forestry” (with forest policy and information, forest training and research, forest area planning, forest resources, forest protection, etc.) is essential concerning innovation and timber construction.

Further important to mention are the departments “sustainability and rural areas” (with research and development, training and service, sustainable development, subsidies of environmental measures, modernization, innovation and market structure, etc.) and the department of general environmental policy (with environmental economics, energy policy, environmental protection, etc.) (BM:LFUW 2013).

Federal Ministry of Transport, Innovation and Technology (Bundesministerium für Verkehr, Innovation und Technologie) (BM:VIT) is responsible for applied research, technology and innovation development. Its main tasks are to encourage companies’ research investments and to foster cooperation with research institutions through financial support and subsidies. In addition, strategic coordination with other ministries due to shared interfaces is essential in order to account for the significance of research, technology and innovation as an interdisciplinary matter (BM:VIT 2013).

Further important to mention within the Austrian Federal government is **the Federal Ministry of Science and Research** (**Bundesministerium für Wissenschaft und Forschung)** (BM:WF) due to its areas of responsibility concerning research and educational institutions. The Ministry´s scope of responsibility includes the determination of framework conditions and being a centre of communication or contact point between students, teachers and all people interested in science and research (BM:WF 2013).

2.3.2.2. Administrative bodies of the provincial government (Ämter der Landesregierung)

Austria is a Federal State, composed of 9 autonomous “Bundesländer” (provinces) (Burgenland, Carinthia, Lower Austria, Upper Austria, Salzburg, Styria, Tirol, Vorarlberg and Vienna). A provincial government to be elected by the Diet exercises the executive power in each province.
If the Federal Constitution does not assign a matter explicitly to the Federation for legislation or also execution, it remains within the provinces’ autonomous area of responsibility.
The governor, who represents the province externally, is the political head of the provincial government and together with it, forms the highest executive body in matters of provincial administration (B-VG 2010, Article 102-105).

The capital city of Austria, Vienna, is all at once, city and province.
"For the Federal capital, Vienna, in its capacity as a Land, the municipal council has additionally the function of the Diet, the city senate the function of the Land Government, the mayor the function of the Governor, the City administration the function of the Land Government Office, and the city administration´s chief executive the function of the Land administration's chief executive" (B-VG 2010, Article 108).

Building law and regulations concerning construction, subsidies or fire police are subject to the province government. As a result, Austria has in each province varying regulations, thus nine different building laws or regulations respectively.

2.3.2.3. Construction authority and fire authority (Baubehörde und Feuerpolizei)

Based on the varying building regulations in the provinces, administrative bodies and their respective responsibility as construction authority is individually regulated as well. In most provinces the mayor represents the construction authority (or the magistrate for cities with their own statute), in Vienna the municipal department 37 (municipal building inspection).
When a building project extends over two or more communities or it is a building for the Federal state the responsibility is delegated to the relevant district commission (B-VG 2010).

The construction authority is responsible for building concessions, building works as well as monitoring and surveillance of building works. Other important tasks are consulting services in regard to constructional questions or building regulations.

According to article 118, subparagraph 3 (B-VG 2010) the community is responsible for the local fire authority as well. Under current law, the competent body of the community is the brigade commander.
The fire brigade has to participate in building negotiations of the community authorities to have the opportunity to make representations and deliver expert opinion.

2.3.3. Relevant interest groups for the timber construction sector

2.3.3.1. Compulsory interest groups (Gesetzliche Interessenvertretung)

2.3.3.1.1. The Austrian Federal Economic Chamber (Die Wirtschaftskammer Österreich)

The Austrian Economic Chamber represents the Austrian business in economic and socio-political affairs and defends its members´ interests. As the voice of Austrians business with more than 400000 member companies, it encourages future oriented strategies which benefit the economy e.g. tax relief or subsidies. In addition, the Chamber is the first contact organisation for members who need information or advice and offers professional preparation of expert knowledge (WKO 2013).

The legal representation of interests for the Austrian business is undertaken by the Economic Chamber Organisations, which consist of the Austrian Federal Economic Chamber (headquartered in Vienna) and nine regional Chambers in the relevant provinces.
Both, the Federal Economic Chamber and the regional Chambers are divided into 7 industry sectors. These industry sectors are divided into trade organisations (Fachorganisationen) and are known as trade groups (Fachgruppe) in the regional Chambers and trade associations (Fachverbände) in the Federal Economic Chamber.
Quantity, effectiveness and specification of the sections are taken together under consideration of representation of membership´s interest, the presence of similar interests of occupational groups, the economic relevance, number of members as well as cooperation with international trade associations (WKO 2013).

Relevant trade organisations concerning the timber construction are the “Bundesinnung Holzbau” as representation of carpenters from the sector “crafts and trade”, the trade association of timber industry and the trade association of the building industry from the sector “industry”.
The trade association of the Austrian timber industry is divided in 6 occupational groups: construction, furniture, panel, saw, ski and mixed.
Especially relevant for the timber construction is the occupational group “construction” as representative of building dependence sectors, like windows, doors, timber constructions and components treat with size.
Further important to mention is the occupational group “panel” as representative of the building supply industries with the chipboard -and fibreboard industry (WKO 2012).

2.3.3.1.2. The Austrian Chamber of architects and consulting engineers (Die Kammer der Architekten and Ingenieurkonsulenten)

The Austrian Chamber of architects and consulting engineers is a public corporation and trade association of officially recognized freelance civil engineers (architects and chartered consulting engineers).
The Federal Chamber is headquartered in Vienna and responsible for the representation of occupation, economical and social interests on a national level. Its members are 4 regional Chambers in the relevant “Bundesländer” (Vienna, Lower Austria and Burgenland; Styria and Carinthia; Upper Austria and Salzburg; Tirol and Vorarlberg).
The Federal Chamber is divided in the Federal section of architects and the Federal section of consulting engineers which are both the legally mandated body representing the interests of independent architects and freelance engineers.
These Federal Sections are again divided in 8 Federal specialist groups whereby the groups “civil engineering and infrastructure” and the “agriculture, forestry and biology” are noteworthy.
Its main tasks are the establishment and improvement of profession conditions and observe and encourage social and economic interests (bAIK 2012).

Further to mention is the “Arch+Ing. Akademie”, established by the regional Chamber of Vienna, Lower Austria and Burgenland in the year 1998. The “Arch+Ing. Akademie” is an independent managed company with limited liability (GmbH) and is financed exclusively through operational business without usage of membership fees.
Principal tasks, defined through the Chamber law, are the functional training and topics that present challenges for the profession and its partners. It offers its members the state of the art, legal framework, know how plus information presented in seminars, workshops and courses or as information events in whole Austria. (Arch+Ing. 2013).

2.3.3.2. Voluntary interest groups (Freie Verbände)

2.3.3.2.1. The Austrian Trade Union Federation (Österreichische Gewerkschaftsbund) (OEGB)

The Austrian Trade Union Federation (OEGB), founded in 1945, is the only organization representing the interests of workers based on voluntary membership. It

is a nonpartisan organisation and together with its trade unions, represents the interests of all employees, the unemployed, pensioners and people in vocational training, towards policy, state and employer.
According to the OEGB (2013) it has 1,2 million people as members.

The OEGB is the umbrella organisation of seven trade unions whereby the members belong to the relevant union according to their occupational field.
It stands and fights for fair working environments with good labour conditions, fair income and strong participation possibilities.
In its efforts to achieve its goals it does influence politics. Main functions are the development of new laws through drafting of bills and providing political reviews of and comments on bills submitted by other bodies, which are then incorporated in the decision-making process. The members are entitled to legal advice and representation in court. Further, they profit from the great number of collective agreements negotiated by the OEGB trade union at industry level. This dense network of collective agreement regulates i.e. working hours, wage agreements, overtime compensation, etc. (OEGB 2013)

The Union of construction and woodworkers (GBH) is responsible for employees in occupational areas such as civil engineering, construction ancillary trade, construction industry and ceramic and material industry, woodworking industry and trade and related sectors. According to the OEGB, the Union of construction and woodworkers has 116.157 members (stand 2011/12) (OEGB 2013).
The GBH is represented by an organisation in the relevant province; structure and principles of the GBH are defined in the internal regulation of the OEGB. Main tasks comprise union activities regarding attractive working conditions, initiation of laws, individual,- business and wage agreements, promotion of economic democracy, protection, improvement and expansion of occupational health and safety, generation of educational institutes, technical publications and so on.
Further, it offers its members support and advice pertaining to labour law, training opportunities, direct support in companies and much more (GBH 2010).

2.3.3.2.2. Cooperation platform Forest Wood Paper (Kooperationsplattform Wald-Holz-Papier)

2005, six organisations found the cooperation- and communication platform for the entire forest and paper industry to have the ability to represent common interest.

Forest Wood Paper (FHP) is a coordination and communication platform of the Austrian forestry, timber industry, paper and pulp industry with the aim to offer an optimal support for companies in the value chain forest-wood-paper. In its efforts to reach the objectives, the FHPs points of focus lie in wood availability, construction material wood, energy, wood balance and wood promotion. Further aims are strengthening relevancy of the whole timber supply chain towards policy, economy and society and to organise framework conditions for the cross-sectorial cooperation. Its vision is a positive and intensive cooperation between the relevant companies and their organisations at all levels for an increased added value and enhanced wood utilisation.
The FHP develops and merchandises innovative, wood-based products as well as new, intelligent applications of wood. Further, the cooperation platform takes over leadership concerning topics such as research, education, standardisation and marketing at European Level.
It's a unique amalgamation of the forestry, wood and paper industry, where representatives work on collective matters of interest and meet in various working groups along the whole supply chain all over Austria.
An executive committee is the decision-making body of the cooperation. A strategy group, consisting of representatives from the main member organisations and relevant industry groups, under the direction of a FHP-chairman, are responsible for the preparation of the strategic direction and basis of decision-making (FHP 2013).

2.3.3.2.3. The Austrian Wood Glue Construction Association (Österreichischer Holzleimbauverband) (OELV)

The Austrian Wood Glue Construction Association exists for more than 25 years and guarantees the quality as well as the optimum performance of its member companies.
The OELV consists of member companies, engaged in glued wood preparation and processing companies. It encourages its members in terms of specialised knowledge and performance quality as well as planning and monitoring of the overall project. The member companies receive latest insights regarding technology, production and safety through permanent cooperation with national and international scientists.
The purpose of the association is the promotion of engineering timber construction in economy and technology (OELV 2013).

The OELV has proved a recipe for these achievements. Moreover, it is a contact and service point for building contractors, planners, constructors and master carpenters. In addition, the OELV has a mark of quality, authorised through the BM:WFJ (OELV 2013).

2.3.3.2.4. MH Solid Timber Austria (MH Massivholz Austria)

“MH Massivholz Austria”, founded 2004, is a manufacturer community of future-oriented timber mills, supported intensively through the trade association of timber industry.
The association consist of 10 member companies, 1 honorary member and 3 passive members.

It gives advice and support to small and medium sized enterprises with the aim to increase the production of high quality and well dried timber. Further aims are the manufacturing of solid wood products produced after explicit criteria and a collective marketing of these products.
Every interested timber mill that accepts and agrees the statutes as well as controls within the quality management can join the association.
Authorized association members obtain a licence to produce and distribute 3 special versions of solid wood (MH-Plus, MH-Fix and MH-Natur).
“MH Massivholz Austria” is a completely organic alternative as compared to glued or chemically treated timber products. Local added value and short routes of transport are an essential part of this processing method.
As a member, certificated after “MH Massivholz” criteria, it can offer certified products with specified quality properties for the modern timber construction.

Within the quality management, the members accept, the quality definition of MH products. The object of quality management is the possibility to offer a high quality and verifiable timber (MH Massivholz Austria 2013).

2.3.3.2.5. The Austrian Association of Prefabricated Housing (Österreichischer Fertighausverband) (OEFV)

The Austrian association of prefabricated housing, founded 1979, is an independent quality organisation and represents the domestic prefabricated house sector. According to the OEFV (2013), it has 22 full member companies (prefabricated

house producers) and 30 associate members, mainly in the cooperating supply industry.
All prefabricated house producers as well as suppliers, admitted to the association, have to fulfil quality standards and restrictions, which are regularly controlled by an independent, accredited testing institute to ensure highest quality standards.

The objectives of the association are encouragement of the image and further development of prefabricated houses in Austria as well as to represent its members towards public authorities, legislation and competitors.
The association offers its customers both, quality and safety due to the certification mark as well as service and information regarding house construction.
An independent civil engineer in the role of an ombudsman is responsible for difficulties of any kind and acts as impartial mediator.
Further the association supports training and advanced training and looks after pubic relations and marketing.

According to the OEFV (2013) the market share of prefabricated houses is more than 30% in Austria whereby timber frame constructions are with 85% the most popular construction type.

Further important to mention is the European association of prefabricated housing with Austria and Germany as founding members. The purposes of this amalgamation are transnational quality standards, involvement in European standards and realization of cooperation research projects (OEFV 2013).

2.3.3.2.6. pro:Holz Austria

Pro:Holz Austria, a working team of the Austrian timber industry, acts as professional and direct contact for architects, engineers and planners, builders, communities and consumers who want to use expert wood advice service.
Founded 1991 by the timber association of the Austrian wood industry and the bodies of wood and building material trade, both are still represented as full members. Promoting members of pro:Holz are the forest departments of the Austrian Chambers of Agriculture, the guild of carpenters, the guild of joiners and further interest groups.

Objectives are an extended use of the regional, sustainable and renewable resource timber and therefore the increase in added value in timber industry.
These objectives are reached by marketing und image-related activities regarding the general public, provision of information and advice to experts and political decision makers as well as creation and maintenance of platforms and networks.
Other points of focus lie in the promotion of local wood, wood materials, products and applications in export markets, communication and development work for innovations in technology and architecture as well as promotion of education.
To sum up, the main aim is qualitative and economic customer benefit during the building process, in respect of performance, availability, sustainability, intelligence and compatibility.

Pro:Holz Austria is represented through provincial organisations in all provinces of Austria, excepting Vienna and Vorarlberg. Their range of functions are the same as of pro:Holz Austria, but with emphasis on regional wood-marketing. Further, it's a regional contact point for all people interested in timber as construction material (pro:Holz 2012).

The working team seeks to increase the appreciation of wood and timber constructions with targeted activities like:

"Zuschnitt":
Zuschnitt is a technical journal about timber construction and wood as material and is published every three month whereby the media owner, editor and publisher is proHolz Austria. The journal has 15.000 number of copies and is addressed to experts and decision makers. Beside the central theme of an edition, it presents timber construction projects, realized constructions, facts and further information regarding wood (pro:Holz 2012).
"Dataholz.com":
Dataholz.com is a cooperation project between the trade association of the timber industry, sector group construction (overall project management), "Holzforschung Austria" (project management – contents) and pro:Holz (project management – marketing). It is a catalogue of reviewed timber building components for thermal, acoustic, fire performance requirements and ecological drivers approved by accredited testing and research institutes. Dataholz.com provides architects, designers, building authorities and builders with a collection of approximately 1500

timber construction and component connections. These approved parameters are accepted by Austrian building authorities without further testing or proof.
This digital catalogue represents an absolute novelty in the construction industry with the main objectives of a simplification and shortened planning phase. Expensive proofs regarding fire, thermal and acoustic performance by the individual can be substituted by a reference to or a submission of these datasheets.
The content of the catalogue is continuously being updated and expanded (pro:Holz 2012).

Genial wood jobs days (Geniale Holzjobs Tage):
The genial wood jobs days are organised from proHolz Austria in cooperation with the 4 provincial proHolz organisations Upper Austria, Salzburg, Styria and Tyrol as well as future-oriented companies in the timber and paper industry.
Once a year it opens a chance for pupils and students to learn about varied occupational possibilities directly in the companies and establish contacts by on site discussions.
191 companies and 2500 pupils and students attended in the year 2012 (pro:Holz 2012).

Timber construction prize (Holzbaupreis):
The timber construction prize, awarded the first time 1997, is conducted in all nine provinces in Austria whereby the implementation varies (see methodology). In the meanwhile the prize is well respected among experts, executive companies and customers.
The prize is organized by the relevant provincial pro:Holz organisations (in Vienna and Vorarlberg from pro:Holz Austria).
Objectives are the presentation and distinction of innovative, exemplary timber constructions in different categories, timber construction marketing and quality improvement in dealing with timber as construction material. Finished projects can be submitted from architects, planners and private customers (pro:Holz 2012).

2.3.3.2.7. Further organisations/ societies

Aside from organisations specialized on energy efficient timber / wood construction there exist a huge number of further platforms, organisations and societies for architects and business in the field of green buildings. They work on sustainable development in the area of building and innovation and are highly concerned with improving resource production processes, sustainable product design or use of renewable raw materials.

Examples concerning architects are the "Österreichische Ingenieur,- und Architekten Verein" (OEIAV) (Austrian Society for Engineers and Architects), the IG Architecture or the Austrian platform for architectural policy and building culture.
Examples in regard to the green building business are the "Österreichische Ökologie Institut" (Austrian Institute for Ecology), the "Österreichische Energieagentur" (AEA) (Austrian Energy Agency) and the "Österreichische Gesellschaft für Umwelt und Technik" (OEGUT) (Austrian Society for Environment and Technology).

2.3.4. Research and Development Institutions, Vocational Education and Training

In Austria exist various possibilities to get an occupation in the timber industry. The qualification for carpenters or joiners happens within the framework of apprenticeship with accompanying vocational school. After 4 years, when finished the apprenticeship, it is possible to do a master exam as completion.
In the framework of grammar schools (AHS), vocational schools with higher education entrance qualification (BHS) or technical schools (HTL), pupils have to finish 4 or 5 years at school with the chance of enrolment at university afterwards. There exist a huge number of these schools in Austria, to name but a few:
The HTL in Pinkafeld (Burgenland), Hallein (Salzburg), Mödling (Lower Austria) and the "holztechnikum" Kuchl (Salzburg), are all specialised in wood technology or constructional engineering and timber construction.

In addition, there are a huge number of colleges (FH) and advanced vocation training possibilities concerning timber construction in whole Austria.

2.3.4.1.Relevant Universities in Austria

In Austria, several universities accommodate diverse departments, institutes and various experts, which concentrate intensively on wood/timber research and education as well as energy efficient timber constructions.

2.3.4.1.1. University of Natural Resources and Life Sciences (Universität für Bodenkultur) (BOKU)

The University, founded in 1872, considers oneself as a training and research institute with the focus on renewable resources. Main task is a significant contribution to protection of these natural resources for the next generation due to diversity of subjects. The university seeks to foster know- how about ecological, economical and sustainable utilization of resources due to the connection between natural sciences, economic sciences and engineering.
Important characteristics of the research at BOKU are practice-orientation, internationality and interdisciplinarity.
The University consists of 15 departments and offers 9 bachelor- and 25 master programmes for more than 10000 students (BOKU 2013).

Technically, the most essential departments regarding timber construction are the department for material sciences and process engineering with the institute of wood science and technology as well as the department of civil engineering and natural hazards with the institute of structural engineering.
Based on innovation, economical and socio-political topics, the department of economics and social sciences with its institute of forest, environmental and natural resource policy and the institute of marketing and innovation combines economic, social, political and legal research activities.
Further important is the department of Forest and Soil Sciences with the mission of forest research and scientific education in (forest-) ecosystem analysis and management (BOKU 2013).

2.3.4.1.2. Vienna University of Technology (Technische Universität Wien) (TU)

The TU Vienna, founded in 1815, is Austria´s largest scientific-technical research and educational institution and among the most successful technical universities in Europe. It places great emphasis on basic research and interdisciplinary as well as on inclusion of students in research programmes (research based teaching).
The TU Vienna consists of 8 faculties with 52 institutes and offers 18 bachelor- and 44 master courses for more than 27000 students (TU Wien 2013).

Based on constructional science, the faculty of architecture and regional planning with its institute of architecture and design and the institute of architectural sciences

as well as the faculty of civil engineering with its institute of building construction and technology and the institute of structural engineering are essential to mention.
Most relevant concerning timber construction is the institute of architectural sciences with its double department “structural design and timber engineering”. Based on the principle that architectural quality cannot be separated from the applied technology, it works in the area where architecture and technology meet between creativity and science. Its research and teaching activities covers to main fields: structural design for architects and timber construction for architects and civil engineers.
Further interesting to mention is the postgraduate master programme Urban Wood with the research and teaching focus on wood architecture in urban regions (TU Wien 2013).

2.3.4.1.3. Graz University of Technology (Technische Universiät Graz) (TU Graz)

The TU Graz was founded in 1811 as “The Joanneum” whereby 1864, the Styrian government makes it an institution of higher education. It pursues top teaching and research in the fields of the engineering sciences and the technical-natural sciences. An integral part of excellent training and education programmes is its knowledge oriented, applied research and research –oriented teaching. The University cooperates with both, partner universities and extra university facilities within the framework of international networks and establishes close contact to industrial and commercial partners that guarantee practical education, profound knowledge of the subject and high degree of problem solving capability.
The TU Graz consists of 7 faculties with 101 institutes and offers 19 bachelor- and 36 master programmes for more than 12000 students (TU Graz 2013).

Important to mention in the context of timber construction are the faculties of architecture and the faculty of civil engineering. Within the faculty of civil engineering the most relevant institute is the institute of timber engineering and wood technology with main topics such as timber engineering, wood preservation, structure in timber as well as assessment and maintenance of timber structures.
Dealing with these timber topics comply with societies requirements regarding sustainability and resource efficient constructions in consequence of global energy problems and associated with the CO2 topic (TU Graz 2013).

2.3.4.1.4. University of Innsbruck (Universität Innsbruck)

The University of Innsbruck, founded in 1669, is the biggest and most important research and education institution in western Austria. It provides a broad spectrum of programs in the diverse scientific fields and cooperation with numerous international research institutions. The University offers the advantage of collaboration between the diverse disciplines, resulting in comprehensive course choices.
The university consists of 16 faculties with 79 institutes and comprise approximately 27000 students (Universität Innsbruck 2013).

Most important in the context of energy efficient timber construction is the Institute for Structural Engineering and Material Sciences with the Unit for Energy efficient buildings and the unit for timber engineering.
The unit for timber engineering was founded in 2002 by proHolz Tirol in cooperation with the province Tirol and the University Innsbruck. Its research focuses are development of new wood products, innovative building envelopes and quality management regarding timber constructions. The institute puts great emphasis on practice-oriented research and close cooperation between architects and engineers. Further focuses are on the study of sensible utilization of local wood reserves as well as ecological aspects from overall concepts (Universität Innsbruck 2013).

2.3.4.1.5. University of Art and Design Linz (Kunstuniversität Linz)

The university, founded in 1947, and its program were conceived as an explicit statement to signify culture-political dissociation of the previous art policy of the National Socialist era.
In the past as in the present, the focus is on fundamental values of freedom of art and research, commitment to modernism and contemporary art and the positioning as an interface of free artistic and applied-economically oriented design.
The university consists of 4 institutes, 8 bachelor- and 12 master programmes (Kunstuniversität Linz 2013).

Essential to mention within the art and technical studies is the master programme architecture. It offers the possibility of choosing a specific profile within the overall field of architecture, such as sustainability, wood and timber construction or architecture in developing countries.

The master course “überholz” is a unique, extra-occupational course for professionals who want to specialize in future oriented timber/wood constructions. It is organised by the University of Art and Design in cooperation with the “Arch+Ing Akademie” and the “furniture and timber construction cluster”.

Target groups are architects, civil engineers, graduates of higher technical institutes, master carpenters, representatives of the timber/wood and construction industries and building administration experts with solid professional experience.
Main tasks of the interdisciplinary course are development of a common basis to promote cooperation, strengthening of project development, a wide range of lectures given by national and international timber construction experts as well as contacts with and access to a regional expert network.
The course seeks to prepare the ground for innovative, high quality timber structures (Kunstuniversität Linz 2013).

2.3.4.1.6. Donube University Krems – University for Continuing Education (Donau Universität Krems)

The university, founded in 1994, has specialized in continuing education and is one of the pioneering institutions in Europe in the field of university-based advanced education. In teaching and research it is focused on social, organizational and technical challenges of current times as well as on interdisciplinary cross-linking and future oriented special sectors. The university consists of 3 faculties whereby 6239 students (winter term 2011/12) from 76 countries can choose from 237 courses and approximately 60 seminars (Donau Universität Krems 2013).

Important to mention in the context of energy efficient construction is the faculty of education, arts and architecture with the master course future building solutions. The international Master program for sustainable and energy efficient building design, exclusively developed for professionals, is offered extra occupational and is oriented towards participants needs. Architects and engineers receive an extensive overview and international information on the topics of sustainable building design, cutting-edge knowledge and leading know- how in the field of building technologies and concepts, like the Passive house technology. Additionally, the program offers its participants key skills to plan, optimize and implement sustainable and energy efficient building projects and benefit from an international future building network. Within the program participants have to choose between two areas of specialization: climate engineering and solar architecture.

In the meantime, people from twenty countries have already profited from the program, taught by an international team of professionals and scientists (Donau Universität Krems 2013).

2.3.4.2. Other relevant Research Institutes and Auditing Agencies (Andere relevante Forschungsinstitute und Prüfungsstellen)

2.3.4.2.1. Timber.construction research gmbh (Holz.bau forschungs gmbh)

The “holz.bau forschungs gmbh”, based in Graz, is initiated in the context of the promotional program COMET (Competence Centers for Excellent Technologies) and is linking basic science oriented research and educational work of the university and the practical oriented work of companies in the field of wood and timber economics. In close cooperation with the institute of timber engineering and wood technology (TU Graz), it organises several seminars, specialist conferences and workshops where current research results are represented with the aim to strengthen the connection between science and economy.
The holz.bau forschungs gmbh has its core competence in the area of working on research questions of timber engineering and wood technology.
The research program consists of the following 3 main areas:

- Solid timber solutions and components (STSC)
- Advanced production, modelling and design (APMD)
- Screwing, gluing and system connections (SGSC)

Further functions are the development, the pre-processing and the targeted transfer of know-how to reach a maximum potential of implementation of the material wood in the building industry.

The centre of competence is concerned with both, short-term, result oriented research services and medium-and long-term research topics.
Provider of funds are on one hand the Federal Government of Austria (BM:WFI, BM:VIT) and the Government of the province of Styria. Shareholders are research institutions like the Gaz University of Technology, and the Joanneum Research gmbh, the woodcluster Styria gmbh and companies in the field of wood (holz.bau forschungs gmbh 2013).

3.4.4.2.2. Competence Center Wood GmbH (Kompetenzzentrum Holz GmbH) (Wood k plus)

Wood k plus, located in Linz, is a competence center for excellent technologies within the national funding programme COMET as well. It is a partnership project of various companies and research institutes representing the leading Austrian research institute in the areas wood composites and wood chemistry. The multidisciplinary and international team develops and optimises state of the art methods and engineering processes. The results are the basis for a new generation of innovative timber products and technologies.

Main tasks are planning and implementation of projects in basic research, industrial research and pre-competition development. Further, it offers support in acquisition of development funds and services such as consulting services, analyses, testing, feasibility studies and counselling. Due to its cooperation on a national and international level and its business and scientific partners (BOKU;TU Vienna, Holzforschung Austria), Wood k plus offers an excellent mix of fundamental and application know-how.

It is funded by 3 provinces of Austria (Upper Austria, Lower Austria, Carinthia), 2 universities (BOKU, Johannes Kepler Universität) and by the "Österreichische Forschungsförderungsgesellschaft "(FFG) (Austrian Research Promotion Agency) (Wood k plus 2013).

2.3.4.2.3. Wood Innovation Center (Holzinnovationszentrum Zeltweg) (HIZ)

The innovation center is a unique partner project of 10 communities in Styria in cooperation with the Styrian Wood Cluster GmbH, founded in 2001, which seeks to use the strength of all regions to keep timber companies in the region and foster new settlements of these. The Styrian Wood Cluster GmbH has over the management whereby the provinces, several timber companies and a bank are common shareholders.

It is a 40 ha industry land that offers business- and office space and necessary infrastructure for new wood application or research and technological development with best price-performance ratio.

Its guiding ideas are the enhancement of synergies of wood working and processing companies to use the enormous market potential of the resource timber collectively as well as preserve and reinforce the added value and expand it in future (HIZ 2013).

The range of service covers the leasing of business area, seminar rooms, event areas as well as professional project- and innovation management. It´s a well-known hotspot for workshops and meetings in the branch and offers space up to 80 people.

Another important part of the HIZ is the Engineering Center Wood, a perfect equipped prototype factory accessible for companies. The Engineering Center Wood offers place for innovative product tests without turn off one´s own production capacity and without loss of output of main business, thus represents an important basis for innovation projects in the region (HIZ 2013).

2.3.4.2.4. Austrian Society for Wood Research (Österreichische Gesellschaft für Holzforschung) (OEGH)

The Austrian Society for Wood Research (OEGH), founded in 1948, is a non-profit organisation, which founded “Holzforschung Austria” in 1953 and established HolzCert Austria as a certification body in the year 2001. Main functions of the OEGH are the development of research and testing in the entire wood field and the dissemination of research results and information in practise.
Members are companies, institutes and individuals from the entire wood industry (OEGH 2013).

Holzforschung Austria (HFA)

Holzforschung Austria is a fully owned subsidiary of the Austrian Society for Wood Research and began its work upon the request of the Austrian Timber industry in the year 1953. With 87 employees (as of 2010) the institution is the largest and oldest research and testing facility for wood in Austria. In the year 2010 Holzforschung Austria had an annual turnover of 6,41 million euros. Basis for the economic success was the received orders of the industry, mainly in the areas of research, testing, inspection and expert assessments (HFA 2013).

Holzforschung Austria is an applied independent research institute, which is accredited for all relevant testing and inspection procedures (concerning wood products and their manufacturing processes) by the Federal Ministry of Economy, Family and Youth (BM:WFJ) and the Austrian Institute of Construction Engineering (OIB). Its testing and inspection reports have the status of officially recognised and valid documents and are internationally recognised (HFA 2013).

Its main areas of responsibility are to foster innovation development among the wood industry through research and development, to provide quality assurance for its customers through testing and company surveillance as well as know-how transfer.

The HFAs working areas are divided in 8 key subjects:

- Raw materials
- Wood-based products
- Wood preservation
- Timber construction
- Joinery / Furniture
- Pulp/ paper
- Chemistry/biology
- Bioenergy

Further tasks are the distribution of know-how to the industry through publications, education seminars, training courses, workshops and in house training.
Based on close cooperation with small and large companies, research activities and projects are practice oriented to maximize customer benefit. For its customers the accreditation is an important and often legally required precondition for having their products accepted in different markets.
Another important part is the industrial competence centre wood technology, established in 2002, which offers a basis for innovations and serves frequently as an external research and development department for its clients (HFA 2013).

HolzCert Austria

Based on the fact that the certification, thus the attestation of a product´s conformity by an impartial independent third party, is organisationally separated from testing and inspection, HolzCert Austria was founded as the independent and competent certification body for timber and forest products of the Austrian society for wood research (OEGH) in 2000.
It has been accredited since 2003 by the decree of the BM:WFJ and in collaboration with its sister organisation holzforschung Austria, it can offer its customers all required services (testing, inspection and certification) as a one-stop shop.
Members are companies, institutes and individuals from the entire wood industry whereby the OEGH is the sponsoring organisation (Holzcert Austria 2013).

Its range of service includes conformity assessments and certification for wood products in the regulated and voluntary sector.
The main business operating areas are:

- The Chain of Custody according to the “Pan-European Forest Certification” (PEFC) and to the “Forest-Stewardship Council” FSC
- Austrian construction products directive (CE marking for wood based panels)
- ÜA-Marking: Authorised body of the Austrian Institute for Construction Engineering (OIB)

Approximately 300 companies in Austria ranging from traders of round timber to sawmills and wood processors, the paper and particleboard industry and even printing shops uphold commitments with respect to the “Pan-European Forest Certification”.
Aside from the traditional forest products, HolzCert Austria offers certification for related products like windows, doors and building hardware as well (HolzCert Austria 2013).

2.3.4.2.5. Austrian Institute for Building Biology and –Ecogoly (Österreichisches Institut für Baubiologie und –ökologie) (IBO)

The Austrian Institute for Building Biology and -Ecology, founded in 1980, is an independent, scientific non-profit society. Its main task is the provision of information on the impact of buildings on human health and well-being (building biology) and on the environment (building ecology). Another important task is the implementation of research projects to investigate the interactions between people, buildings and environment.
The areas of responsibility are consultations and measurements like passive house consulting, optimization of building ecology, comfort analyses, room climate simulations and thermal building simulations.

All activities are financed due to the payment of an entrance fee and a certain annual amount of its members, which can be individuals, experts and companies who attach importance to green buildings.
Its members profit from direct access to up-to-date information by means of the quarterly IBO-magazine or the IBO specialist library and get benefits and reductions regarding prices for indoor measurement and building consulting services (IBO 2013).

Further, the institute is a founding institute of the Austrian Sustainable Building Council (OEGNB 2013).

2.3.4.2.6. Austrian Sustainable Building Council (Österreichische Gesellschaft für nachhaltiges Bauen) (OEGNB)

The Austrian Sustainable Building Council was founded in 2009 by various independent institutions in the field of sustainable building, like the IBO and the Austrian Institute for Ecology, which are both still board members.
The OEGNB is working in the context of an "open source community", thus a high quality development of the construction industry can be reached only through open cooperation and sharing of knowledge, resources and distribution facilities.
Possible members and partners are all institutions and businesses who want to participate actively in fostering the Austrian building industry and enhancing quality standards in compliance with green buildings (OEGNB 2013).
Members profit from an established network of national and international experts, policy makers and institutions involved in research, business and administration. Additionally, members can actively contribute by helping to define goals and quality criteria for the comprehensive building assessment.

Main aims are the further development of building assessment systems and to offer knowledge, methods and tools to enhance quality standards and to counteract the trend towards expensive brands. It seeks to offer it services, activities and access to information for free of cost to those interested in providing their expertise in the field and those who want to contribute to goals of the Austrian sustainable building council.
Further it wants to encourage its goals with conventions, organised events, PR and the exchange of experience (OEGNB 2013).

Further important to mention is its closer partnership to both, the research program "Haus der Zukunft" (House of Tomorrow), an ambitious and successful R&D initiative in the field of sustainable building and klima:aktiv, a climate initiative of the BM:LFUW (OEGNB 2013).

2.3.4.2.7. Living, Building and Planning Research Association (Forschungsgesellschaft für Wohnen, Bauen und Planen) (FGW)

The Research Association was founded in 1956 by the Austrian Society of Engineers and Architects and since 1969 it is an independent society.
As a non-commercial research institute, the FGW is targeted at public interests and fulfils tasks regarding legal, economic, technical, statistical, political and planning aspects in the field of building industry.
Further it offers a coordinating function between the nine provinces in Austria and their varying subsidies policy.

Its activities are divided in the following three areas:

- Research projects
- Expert assessments
- Events

Committee members (board, research advisory council, provincial advisory council) are representatives from business, science, federal ministries and the financial sector.
Additionally, the FGW is a cooperation partner of the ACR Austrian cooperative research, a non-profit organisation composed of non-university, collaborating research institutes.

Membership is open to institutions and business interested in providing their expertise in the field of sustainable building and those who want to support the goals of the Austrian Sustainable Building Council (FGW 2013).

2.3.5. Relevant Clusters and Networks

In Austria, the “Forum Alpbach” made clusters subject of discussion the first time in the year 1991. Since then, clusters became priority in the Austrian innovation- and economic policy and have an essential role as pioneers, drivers and organizational units in the Austrian national innovation system (NIS).
Despite certain lack of conceptual clarity concerning definitions in Austria their positive effects on competiveness, innovation strength and growth are beyond doubt. Acting as interface between economy, science and politics is their main task (Clement et al. 2009).
The corporate form and orientation varies, depending on the chosen financing model (independence or public/private financing).

The majority of the clusters are rooted in the provinces, a few developed on federal level.
The first organised cluster initiative was the “automobile cluster” Styria.
In the meanwhile, there exist more than 60 clusters in Austria whereby most of them are in the range of “materials” and “green energy and environment” (Clement et al. 2009).

Important to mention and one of the biggest is the cluster type “wood, furniture, living and house construction” with more than 1000 cooperation partners in Austria. The advantages of the sector-specific cooperation are mainly used from rather small and medium sized enterprises (SMEs) like architects, frame carpenter, and timber mills. Main tasks of the “wood, furniture, living and house construction” clusters are imparting of knowledge, the development of a communication-, and cooperation platform as well as a collective marketing (BM:WFJ, 2009).

A summary of the most important clusters, influencing the timber construction industry, is listed below:

- Möbel und Holzbaucluster OÖ (MHC) (Furniture and Timber Construction Cluster
- Holzcluster Steiermark GmbH
- Organisation proHolz Tirol - Holzcluster
- Bau.Energie.Umwelt Cluster Niederösterreich (Green Building Cluster of Lower Austria)
- Vorarlberger Holzbau_kunst
- Business and Innovation Centre BIC Burgenland

The cluster initiatives in Upper Austria (over 250 member companies) and in Vorarlberg (ca. 100 companies) are concentrated on furniture –and wood construction companies, architectural offices and the ancillary industries. The wood clusters in Styria (ca.130 companies) and the Tyrol (more than 90 companies) have their focus on forest and wood management. The “bau.energie.umwelt” cluster in Lower Austria has several areas of responsibility and is associated to both cluster types, “wood, furniture, living and house construction” as well as “ green energy, environment” (BM:WFJ 2010, Clement et al. 2009).

Further important to mention are those cluster types specialised in topics like “green energy and environment” due to their high representation in Austria. Although these clusters are not directly active in the forest and wood management or timber construction sector, their ambitions and objectives overlap in some areas. Just to mention a few of them:

- IG Passivhaus
- Vorarlberger Architektur Institut (Architectural Institute Vorarlberg)
- Energieinstitut Vorarlberg (Energy Institute Vorarlberg)
- Erneuerbare Energien Tirol (Renewable Energies Tyrol)
- Energienetzwerk Salzburg (Energy Network Salzburg)
- Netzwerk Energieeffizienz (Network Energy Efficieny)
- Netzwerk Umwelttechnik (Network Environment Engineering)
- Ökoenergie Cluster (Eco Energy Cluster)
- Eco World Styria
- Life Science Austria Region
- Energiesparverband Oberösterreich (Energy Agency of Upper Austria)

However, especially important to mention are regional and local cooperation models like “vai: vorarlberger Architektur Institut” or “werkraum bregenzerwald”, mainly realised by small timber construction companies and craftsman.

Vorarlberger Architektur Institut (vai)

Vai was founded 1997 by 20 architects, public representatives and building promoters with the main aim to strengthen a sustainable building culture. Financial basis is composed of public incentives and membership subscriptions whereby members and activities have increased essentially in recent years. Further income is earned through sponsors, studies, lectures, sale of special books and architectural excursions.

The Association acts as an interface between planners, architects, building owners, industry, craftsmanship, science and policy and initiates cooperation projects with universities.

Main tasks are the organisation of exhibitions, awards, symposia and preparation and planning of architectural excursions in Vorarlberg.

Help establish lighthouse projects into local press, citizen´s service and further training possibilities regarding contemporary building culture are additional tasks.

Werkraum Bregenzerwald

Werkraum Bregenzerwald is an association to encourage collaboration of industry and craftsmanship. In the meanwhile it has more than 80 members of varying sectors. Approximately 40% of the members come from the woodworking industry (frame carpenter, joiner, etc.) and 60% come from the building industry as well as from the glass,- metal,- textile,- leather industry. Installers, electricians, town and country planners enlarge the wide rage of varying sectors.

Financial support comes from partners, members as well as 20 municipalities in the region Bregenzer Wald (Bregenzer Forest).

Aims are the encouragement of building culture in generally and to emphasize the performance of craftsmanship in the region in particularly.

Another essential objective is to get young people interested in craftsmanship.

Since architectural pioneering in the 60s, and based on the above mentioned cluster initiatives, Vorarlberg is internationally known for it´s remarkable architecture and building culture characterized by

- consciousness of tradition,
- further development of valid methods and materials such as timber,
- implementation of new technologies
- and suitable for daily use.

Hardly any other region in Europe has such a high density of high quality constructions and shows such an enormous building activity in the last thirty years. Interesting is the fact that in Vorarlberg more than 20% of the buildings are built with wood (Marina Hämmerle, 2006).

Other reasons for that high building standard beside building culture, are the close collaboration and knowledge exchange of many varying experts, industries and sectors and as a result acceptability of the local population.

2.3.6. Relevant Policies

Policies: European Construction Product Regulation (EU Bauproduktrichtlinie), Energy Performance of Building Directive (EU Gebäuderichtlinie) (EPBD), Austrian Building regulation (Österreichische Bauordnung) and OIB Directives (OIB Richtlinien)

As a preliminary point, although there exist no EU or Austrian policies with a specific intent to foster timber framed constructions; there are a number of EU policies, which indirectly promote this construction approach through the promotion of sustainable development and management of climate change (Tykkä et al. 2009).

In this context important to mention are:

a.) European Construction Product Regulation (EU Bauproduktrichtlinie)
The European Construction Product Directive (89/106/EEC) and its new version, the European Construction Product Regulation (EU No.305/2011), have the main purpose to harmonize marketing conditions of construction products in Europe. "Reliable information" about the product performance has to be presented. This is mainly managed through standards.
As a regulation, it becomes direct law (Ludwig and Weiss 2013, 16).

On national level the European Construction Product Regulation is transferred into nation law within the framework of the OIB directives 1-6 (OIB Richtlinien 1-6) (OIB 2013).

b.) European Energy Performance of Building Directive (EU Gebäuderichtlinie) (EPBD)
On EU level the Energy Performance of Building Directive 2002/91/EG" (EPBD) and its new version 2010/31/EU are the EU´s main legislative instruments to decrease the energy consumption of buildings. Especially in the construction sector as one of the largest CO2 emitting sectors worldwide (Ludwig and Weiss 2013, 19) is urgent need for action.
Europe-wide, the method for the assessment of the energy performance is to be made under a uniform procedure (according the directive) (Ludwig and Weiss 2013, OIB 2013).

On national level the Energy Performance of Building Directive 2002/91/EG and 2010/31/EU is transferred into nation law within the framework of the "OIB Richtlinie 6" (OIB Directive 6) (OIB 2013).

Austrian Building Regulation (Österreichische Bauordnung) and the OIB Directive (OIB Richtlinie)

Due to the fact that the Austrian Federal constitutional law (B-VG) includes no matter "building regulations", the consequence being that building regulations remain within the provinces autonomous sphere of competence as laid down in Article 15. (1) B-VG (Federal Law Gazette I No.127/2009) (B-VG 2010).
As a consequence, there exist nine varying interpretations of building regulations in Austria.

The OIB directive serves as the basis for the harmonisation of the varying building regulations and can be used from the provinces for this purpose.
In 2007, it was determined during the general assembly of the Austrian Institute of Construction Engineering (OIB) in the presence of representatives of all provinces of Austria. In accordance with the European Construction Products Regulation (EU No.305/2011) the following six directives regarding constructional requirements for buildings have been established (OIB 2013):

OIB directive 1: Mechanical strength and stability
OIB directive 2: Fire prevention
OIB directive 3: Hygiene, health and environmental protection
OIB directive 4: Safety in use and accessibility
OIB directive 5: sound insulation
OIB directive 6: energy conservation and thermal protection

Its legal obligation as well as the date of entry into force is left to the provinces discretion, thus varies between the nine provinces.

For the implementation of the Energy Performance of Building Directive 2002/91/EG" directive 6 was specially developed to avoid nine varied regulations regarding energy conservation and thermal protection.
EPBD asks all member states

- to define minimum requirements for the energy performance of new and existing buildings
- to ensure increased market transparency for consumers
- certification of their energy performance (result: energy pass)
- regular inspection of boilers and air conditioning system in buildings
- and indicators for CO2 emissions (Version 2010/31/EU).

Directive 6 (energy conservation and thermal protection) is the only directive that came into force in all provinces already.
In the meantime the OIB directives 2011 entered into force since January 2013 in all provinces except Lower Austria and Salzburg. In these two provinces only Directive 6 (version 2007) is in force (OIB 2013).

For further information about policies, norms and standards that currently determine environmental assessments in the construction sector the reader may consult Ludwig and Weiss (2013, 16 et seqq.).
For further information about the "Österreichische Bauordnung" (Austrian Building regulations) and the OIB Directives the reader may consult the OIB homepage: http://www.oib.or.at

2.3.7. Energy efficient building standards

The terms "Passivhaus" (Passive House) and "Niedrigenergiehaus" (Low Energy House) define building standards that can be achieved with different building construction techniques, forms and materials (Krapmeier and Drössler 2001).
These terms are commonly used in place of their energy demand. In Austria both, the energy demand as well as the varying building standards are defined on the basis of the annual heating demand per square meter (kWh/m2 a) (die Umweltberatung 2011)
"Niedrigenergiehäuser" (Low Energy Houses) are standard in Austria in the meanwhile and compulsory when applying for subsidies.
In Austria it is common to distinguish between Low Energy buildings and Ultra Low Energy Buildings. The difference originates through the energy demand as measured by the annual heating demand.
Low Energy Houses have to achieve an energy demand between 50 and 25 kWh per square meter per year and do not necessarily need a ventilation system with heat recovery (die Umweltberatung 2011).

"Niedrigstenergiehäuser" (Ultra Low Energy Houses) have to achieve an energy demand between 25 and 15 kWh/m2a and fulfil almost Passive House criteria. Similarities are the ventilation system with heat recovery and huge, south-oriented translucent areas.

Possible distinctions compared to Passive Houses may are less insulation, less thermal bridges, no Passive House windows or a less compact building envelope. Distinctions are mostly less and may be amended with increased detailed planning. Thus, the Passive House is the next development stage of the Ultra Low Energy House.
Usually, capital costs of Low Energy Houses are a little less than those required for a Passive House, but on the other hand energy costs may be higher (die Umweltberatung 2011).

The **Passive House** concept as well as its name is based on the fact that through thermal optimized building components, additional heating systems (active heating or cooling systems) getting unnecessary.
Passive House is not a brand name but rather an integrated as well as fundamental construction concept assuring the highest level of comfort. It is the only internationally recognised, performance-based energy standard in construction (Passive House Institute 2012).
Passive Houses represent energy conservations of up to 90% compared with typical Central European building stock and over 75% compared to average new buildings and less than common low energy buildings (Passive House Institute 2012).

According to the Passive House Institute (2012) there are three main criteria that a building has to fulfil to be a Passive House.
First, the achievement of a comfortable indoor climate without a conventional (separate) heating system and without an air conditioning system throughout the year serves as basic prerequisite. The passive house may not exceed an annual heating demand of 15kWh/m2a in accordance with the calculation of the Passive House Planning Package (PHPP).
Second, thermal comfort has to be reached for all living areas during all seasons. Internal surface temperature and indoor air temperatures show no considerable differences, even during extreme outdoor temperatures, thus contribute to sense of wellbeing. That is feasible due to special requirements for the heat transfer coefficients (U-value), translucent areas and ventilation efficiency.
Third, the use of specific primary energy for all domestic applications, thus heating, hot water and domestic electricity, has to be lower than 120 kWh/m2a in total in accordance with the PHPP (Passive House Institute 2012).

To fulfil the three above-mentioned criteria the following basic principles are necessary:

- Efficient (passive) use of solar energy through south-orientation and passive house windows (glazing plus window frame should not exceed a heat transfer coefficient (U-value) of 0.80 W/m2K.
- Convenience ventilation with highly effective heat recovery: at least 75% of the heat from the exhaust air is transferred to fresh air by the help of a heat exchanger.
- Thermal bridge free: edges, corners, connections or penetrations have to planned and executed with accuracy and in detail. Those, which cannot be avoided completely, have to be reduced as far as possible.
- Increased thermal insulation: all opaque building components of the exterior envelope of the building have a heat transfer coefficient (U-value) of 0.15 W/m2K, i.e. 0.15 watts per degree of temperature difference and per square metre of exterior surface are lost
- Special windows and a highly insulated building envelope provide both, keep the desired heat inside and undesirable heat outside the building.
- Air tightness of the building: Uncontrolled leakage airflow through gaps has to be decreased to a minimum (smaller than 0.6 of the total house volume per hour during a test with a negative pressure of 50 Pascal).

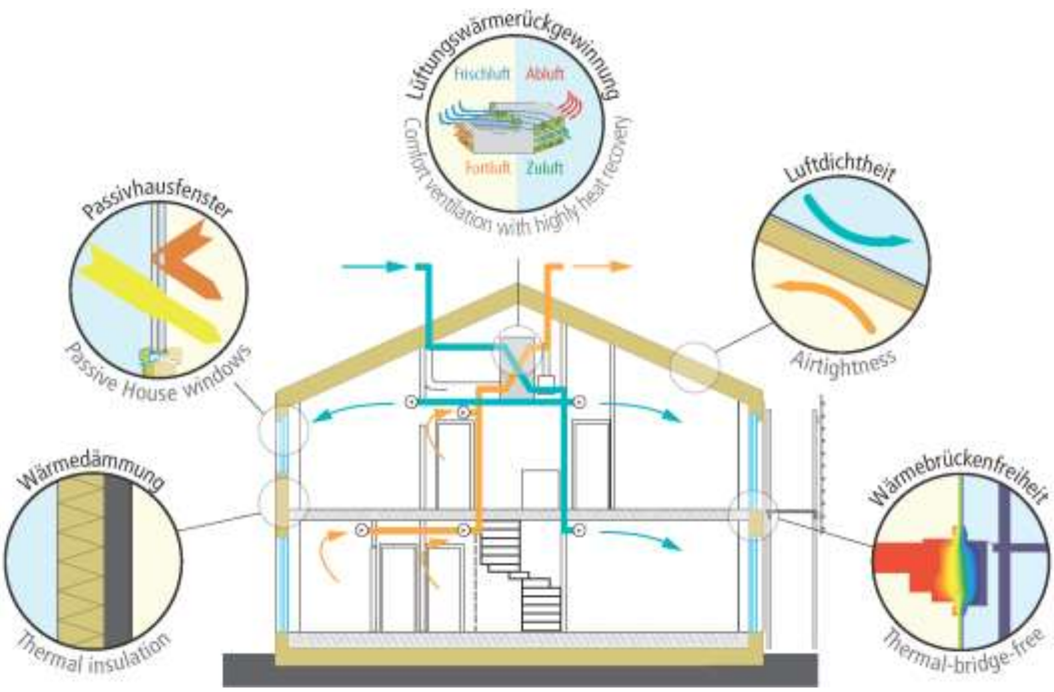

Table 1: Basic principles for the construction of Passive Houses (source: Passive House Institute 2012)

For the realisation of a Passive House, planning right down to the last detail and interaction between different skilled craftsmen is necessary. A well-conceived construction decreases energy losses and increases indoor environmental quality. Passive Houses enjoys a good reputation regarding the high level of comfort due to controlled removal of odours and dump and simultaneously offers greater independence towards unsteady energy prices to its users.
It is energy efficient, comfortable and affordable at the same moment (Passive House Institute 2012).

Although the Passive House concept as well as the building physics behind it stays the same across the world and its varying climate, details have to be adapted to the specific climate on site. A building in Passive House quality in Alaska will look completely different than in Africa.

Further to mention is the “Passivhausprojektierungspaket” (passive house planning package) (PHPP), which is the key design tool and serves as the basis of verification for the Passive House standard. Its high level of accuracy regarding the calculation of the energy balances (+/-0.5 kWh) makes it indispensable during planning (Passive House Institute 2012).

An **“Aktivplushaus” (Active Plus House)** is a Passive House or Ultra Low Energy House, which produces more energy than it consumes per year. That is possible by means of active use of solar energy through either solar thermal plants for hot water production or photovoltaic power plant for electricity generation. (die Umweltberatung 2011)

3. Methodology

The objective of this thesis is the in depth examination of the innovation processes in energy efficient timber construction by use of tangible case studies in the categories “public building” and “commercial building”, built in Austria during the time period 2006 to 2012.
For that purpose, the following subject areas shall be analysed:

- The main actors and their role in the innovation process
- Fostering and impeding factors
- Cooperation, interaction and information flow
- Conflict management and problem solution
- Need for future action
- Trends and challenges for the timber construction in future

The case study analysis was chosen as an appropriate research method. It gives the opportunity to carry out an in depth study, which can cover complexities, relationships and processes (Yin 2009). According to Yin (2009), the case study allows to demonstrate the holistic and expressive characteristics of real life events, such as small group behaviour as well as organizational processes.

After a similar innovation analysis was carried out 2009 by B. Schwarz by using case studies in the categories “ public building” and “residential buildings”, this thesis aims to improve the knowledge in larger business categories.

3.1. Case study selection

In the beginning, before having selected two relevant case studies, a range of innovative timber constructions had to be determined. For this purpose, a two - step approach was chosen as an appropriate method.
First, literature and database research was used to get an overview of innovative timber construction projects built in Austria during the time period 2006 to 2012.
Second, expert interviews were conducted to ensure a professional selection of case studies.

Based on the literature and database research, a scientific concept as well as previous knowledge was already existent. For that reason the problem-centered interview, in detail the expert interview, was used as research method (Lamnek S., 1995).

A standardized questionnaire was used auxiliary during the expert interviews to facilitate the first steps into the conservation and to stay within the scope (Lamnek S., 1995).

3.1.1. Literature and database research

The selection of relevant and innovative timber constructions was made on the basis of

- the timber construction prize in all provinces in Austria realised between 2006 and 2012
- the architectural database “nextroom”
- the “klima:aktiv” construction database
- the state award of architecture and sustainability
- the research and technology program “building of tomorrow”
- and the professional journal about wood as material and timber constructions “Zuschnitt” (edition 21 to 48)

The **timber construction prize** was awarded the first time in Vorarlberg and Carinthia in the year 1997. Meanwhile, the prize is conducted in all nine provinces in Austria whereby the implementation varies between the provinces. In Lower Austria, the prize is awarded every year whereas most other provinces organize it every two or three years. In Vienna was the premiere 2005, called “wienwood 05”, but there was no repetition by now. The timber construction prize is organized by the relevant provincial organisation of proHolz, who provides a good-sorted illustration of all prizes on its homepage.

Innovative construction projects, submitted in different categories, get awarded with prizes, appreciations and nominations by an expert panel. The prizes are aimed to award exceptional achievements in the timber construction sector and to foster enhanced application of the natural resource timber, thus responsible dealing with the source (proHolz 2012).

For the preparation of the case studies, all awards, appreciations as well as nominations in the categories “public building” and “commercial building”, realised between 2006 and 2012, have been taken into consideration.

Jürg Meister, a Swiss architect, founded the **architectural databank “nextroom”** in the year 1996. It is based on an extensive construction, - photography, - and text database, which is nowadays a comprehensive archive of contemporary architecture. Collection partners, like the “architecture centre Vienna”, provide the database continuously with regional architecture and diverse information concerning the topic (nextroom 2012).
Based on this databank, all collections and entries with the search item “timber construction”, completed between 2006 and 2012 were searched. Due to the specialisation on the categories “public building” and “commercial building”, the search was restricted to the building functions “banks and stock markets”, “educational and research facilities”, “offices and administrations”, “mixed utilization”, “health and social services providers”, “hotels and gastronomy”, “industry and trade”, “museums and exhibitions” as well as “ sport, recreation and recovery centres”.

“Klima:aktiv” is a priority initiative for climate protection launched by the Federal Ministry of Agriculture, Forestry, Environment and Water Management in the year 2004. It´s part of the Austrian Federal climate strategy and consists of a range of measures of regulations, taxes and subsidies. Main objective is the establishment and encouragement of climate friendly as well as energy efficient technologies, services and activities with instruments such as training, consulting, quality management, networking and awareness campaigns.
In the four thematic clusters “Building”, “Energy Efficiency”, “Mobility” and “Renewable Energy”, programmes are realised by diverse programme managers of different institutions who follow a systematic and comprehensive approach.
The cluster “klima:aktiv - Building” stands for energy efficiency, ecological quality, comfort and quality in completion, no matter what construction type.
Further, the cluster developed the “klima:aktiv” building-standard, a quality management system, for the purpose to make buildings measurable and comparable to others. On the basis of this standard, “klima:aktiv” awards buildings that meet these special requirements.
Another support method of the “klima:aktiv” cluster “Building” is the construction database of energy efficient buildings. This database informs about flagship projects in practice, which are planned and realized after “klima:aktiv” criteria. Further, all award winners from the state award of architecture and sustainability are part of the database (klima:aktiv 2012).
Based on the construction database, all entries with the search item “timber construction” were searched. The search was restricted additionally through the

categories “public building” and “commercial building”. If they have not been already taken into account, the projects were added on the list.
Further, the database was used as additional information source due to the fact that all projects, found already during the timber construction prize database research, were searched targeted again, to find potential accordance.

The **State award of architecture and sustainability**, tendered by the Federal Ministry of Agriculture, Forestry, Environment and Water Management, was implemented 2006, 2010 and due to great attendance as well 2012. The Ministry awards the prize to distinguished accomplishments from architects, clients and planners that combine ambitious architecture with resource efficient strategies. An important objective is the encouragement of people from the construction sector concerning further development and innovations in future (klima:aktiv 2012). All timber construction winners and nominations were searched and added on the list.

The research and technology program **“Building of Tomorrow**”, established by the Austrian Federal Ministry of Transport, Innovation and Technology in 1999, has laid the foundation for entirely new and sustainable approaches in the construction sector. The program is based on the three most important developments in the field of solar and energy efficient construction: the solar low energy approach, the Passive house and since 2008 the Energy Surplus Buildings, i.e. buildings that generate more energy than they consume.
Objectives are a significant reduction in energy and material consumption, an increased and efficient utilization of replenishable material as well as renewable sources of energy, particularly solar energy. Further, improving quality of life due to cost levels similar to conventional construction and thus considerable market potential are important aims as well.
The program has a pioneering position concerning ecological architecture due to its planning and realization of innovative residential,-public,-and commercial buildings (BM:VIT 2012).
For the research, the technical guide “innovative buildings in Austria” has been searched for energy efficient and innovative timber constructions.
This guide illustrates pioneering new buildings thought out and implemented on the basis of results from the research program “Building of Tomorrow” and provides an overview of demonstration projects and flagship projects already built and in process (as of 2012). Further, this guide is meant to arouse active interest and involvement in new approaches to building (BM:VIT 2012).

It is important to mention that not all timber construction projects had been considered during database literature due to the specialisation on the categories “public building” and “commercial building”.
Further, it is necessary to mention that **“public buildings”** are restricted to buildings with the function education and research, administration, cultural affairs, health and social service, sport, recreation and recovery and mixed utilization, realized for the public with public funds.
“Commercial buildings” are defined as buildings privately operated, conduct private trade and are mainly built with private fund, like offices, hotels and gastronomy, industry and trade as well as banks and stock markets.

Special construction projects, such as towers, roofs, renovation, monuments and bridges have not been considered during database research. In addition, single-family houses and multi-family houses have not been observed.

After literature and database research, the amount of selected construction projects (see table 7) had to be reduced due to the great number of projects. Some **selection criteria** had to be determined prior to the implementation of the expert interviews.
First, due to the thematic priority on energy efficiency, construction projects with **contemporary energy concepts**, thus at least low energy buildings, have been shortlisted. It is important to mention that Passive houses as well as energy surplus buildings have been preferred.
Second, projects with **outstanding innovations** concerning the product itself, such as the design or the construction, as well as process innovations, like technological and organisational innovations, have been favoured.
Third, projects that support the regional value added, thus **local and ecological construction materials** have been shortlisted because of the focus on resource conserving innovations.
To sum up, projects that combine a comprehensive concept concerning sustainability and a range of innovative aspects have been picked out. Based on these selection criteria 26 projects have been put on a list (see appendix).

3.1.2. Expert interviews for determination of the case studies

The main objective of the expert interviews was the determination of two appropriate case studies from the list above, one in the category “public building” and one in the

category “ commercial building”. These two projects are used subsequently for the case study analyses.
The choice of experts happened after personal epistemological interest.
Further, thanks to a personal interview with an expert from proHolz Austria other suitable experts have been recommended.

The selected experts are from various institutions and different professional groups, specialised either on timber research or architecture, to obtain broad knowledge and new insights as well as to ensure a professional selection of the case studies. According to Yin (2009), the examination of the evidence from different perspectives will increase the chances that a case study will be exemplary and credible.
The experts are from national universities with departments specialised in timber research. Therefor, departments and institutes of the University of Natural Resources and Life Sciences, Vienna, the Vienna University of Technology, the Graz University of Technology and the University of Innsbruck have been contacted.
Furthermore, experts from accredited research institutions, working in the timber construction field, such as holzforschung Austria and proHolz Austria, have been approached to conduct interviews.
On the basis of their real life experience, leading architects from the timber construction branch have been consulted as well. There is a detailed list in table 1.

Table 2: List of institutions contacted for the expert interviews

Organisation	**Department / institute**
University of Natural Resources and Life Sciences, Vienna	Institute of Wood Science and Technology
Vienna Universtiy of Technology	Institute of Architectural Sciences- Structural Design and Timber Engineering
Graz Universtiy of Technology	Institute of Timber Engineering and Wood Technology
University of Innsbruck	Institute of Structural Engineering and Material Sciences, Unit for Timber Engineering
Holzforschung Austria	Module timber construction & construction physics
proHolz Austria	proHolz Lower Austria

Architects	

The contacting of the experts happened through E-mail exclusively. The interviews were accomplished preferably personal or by telephone. If this was not possible due to experts lack of time or for reasons of journey, the interview was done per E-mail. This was possible due to the shortness of survey with just two questions (see guideline-appendix) and in view of the fact that it was a standardized interview.

The interviews happened during the time period December 10, 2012 to January 30, 2013. Six interviews have been conducted personally and two per telephone due to the distance (University of Innsbruck and Graz). The duration of the personal interviews was approximately 45 minutes, whereas the telephone interview took 30 minutes.

The list of construction projects, determined through literature and database research, has been expanded after each interview with further innovative projects, recommended by the experts. The final list is in the appendix.

3.2. Case study analysis

The case study analysis was chosen as pertinent research method due to its suitability for studying contemporary phenomena in their real-life context. According to Yin (2009), the case study´s unique strength is its ability to deal with full variety of evidence. It is preferable to use multiple, not just single, sources of evidence for creating a case study database and maintaining a chain of evidence (Yin 2009). According to Yin (2009), a combination of multiple sources increases knowledge, information and credibility. A reasonable approach is to corroborate interview data with information from other sources. A good case study will therefore want to use as many sources as possible.

For the case study analyses various sources were used. Interviews with involved actors (as the main type of survey) served as the main information source. Documentary information, archival records and direct observation served as further sources.

Documentary information, such as news articles, written reports of the project, studies and administrative documents (progress reports) were used mainly to substantiate evidence from other sources (interviews) and are relevant to almost every case study topic. These types of documents had been mainly available online which provided an opportunity to use relevant information as preparation and preconception prior to the interviews.

Archival records like organizational/internal records, survey data, images and plans have been used to receive additional information about the projects.
This type of source played a tangential role compared to the interviews and documentation.
In these cases, archival records (images, building sections or other technical drawings) came primarily from the interviewee or involved companies themselves.

Direct observation, thus building site visits, served as another source of evidence and was useful in providing additional information about the projects being analysed. Observation or on site visits are an invaluable aid for understanding the actual uses of the technology or any potential problems being encountered.
Each case study was visited on site to get a better impression of the construction projects, their workmanship and design in real life as well as their environmental conditions.
In addition, the visits offered the opportunity to take photographs of the construction projects that help to convey case characteristics to outside observers.
Observations add new dimensions for understanding the context being studied (Yin 2009).

As described above two innovative construction projects served as the basis for the case study analysis. As a consequence it is designed as multiple case study. According to Yin (2009, 61) the evidence from multiple cases is often considered as more compelling and is seen more robust.

In this thesis, each project was analysed and described separately at first and checked against each other in regard to the same leading questions later on. Finally, the results were analysed collectively.
Analytic conclusions arising independently from two cases will be more powerful than those coming from a single case alone (Yin 2009).

3.2.1. Interviewing the main actors of the innovative case studies

Personal interviews with the main actors represent the main source of information in this multiple case study analysis.
The interview is one of the most essential sources of case study evidence because most case studies are about complex human affairs and real life projects.
Well-informed interviewees provide important insights into such affairs and are able to tell much about the projects. Through interviews it is possible to ask key respondents about their opinions and views about the progress of events and certain occurrences. Such key informants are often critical to the success of a case study (Yin 2009).

3.2.1.1. Design of the enquiry

Face to face interviews by means of an interview manual (structured after requirements) were used to analyse the innovation process of the preassigned case studies. The object was to determine main actors and their role, fostering and impeding factors, cooperation, interaction and information flow as well as conflict management and problem solving during development and implementation.

The architects and building promoters of the chosen projects have been determined as the most important actors and were contacted.

Table 3: List of interviewed actors for the first case study

Actor	**Organisaton**
Building promoter	Community
Planning and design	Architectural office

Table 4: List of interviewed actors for the second case study

Actor	**Organisation**
Building promoter	Building contractor
Planning and design	Architectural office + building promoter

3.2.1.2. Implementation of the interviews

At first the desired interview partners were contacted per E-mail to inform them about the main purpose and main aims of the thesis and the case study analyses. The appointment of a date was done by phone subsequently. The personal interviews happened in locations familiar to the interviewed persons.

The interview started with introductory words, followed by the expert interview with an interview guide (see appendix) and was completed with final questions. The interview guideline was divided into the following four subject areas:

1. Project development (idea, impulse, preparation, planning)
2. Project implementation (planning, production, construction, completion)
3. Financing
4. Introduction phase on the market and general questions

Part one and two represent the main phases of the projects and have the same formulation of questions.
Following a certain set of open questions, the interview partners were called upon to speak about project development and project implementation in a conversational manner.
The interviews were more guided conversations rather than structured queries. Although pursuing a consistent line of inquiry, the actual stream of questions in a case study interview are likely to be fluid rather than rigid (Yin 2009, 106).
If important questions have not been answered according to the interview guideline, it was asked for them specifically.
In addition, it was tried to question the various phases idea, impulse, preparation and planning as well as planning, production, construction and completion independently of each other, which was not always possible due to fluent passages between the different phases in real life.

The implementation of the interviews happened in February 2013. The building site visits took place within the frame of the interviews at the same time. The duration of the personal interviews was between 60 and 90 minutes.
The interviews have been recorded with the help of a tape recorder in order to provide provision for a more accurate rendition. However, it is no substitute for listening closely throughout the interview. Further, essential statements have been noted in the guideline and a postscript was prepared subsequently.

3.2.1.3. Data analysis

The analysis and interpretation of data, obtained from the interviews, was realised in four phases (Lamnek 1995, 108 et seqq.)

1. Transcription
2. Case-by-case analysis
3. Generalising analysis
4. Supervisory phase

The first phase is more a technical, but necessary prerequisite for the following steps. To analyse qualtitative interviews, it is necessary to make a written transcription of the interviews. The recorded information has to be transcribed from the tape recorder into written form.

Afterwards, each interview has been analysed individually. In this step, irrelevancies were eliminated while key statements were highlighted.

As a third phase, both, similarities and differences have been worked out to analyse results collectively and to obtain empirical findings.

As a last point, self-control by use of complete transcript and tape recording was implemented to avoid abbreviations or misinterpretations (Lamnek 1995).

4. Findings

4.1. Determination of the case studies

4.1.1. Literature and database research

On the basis of the **timber construction prizes** in all provinces in Austria, 53 commercial buildings and 67 public buildings have been determined.
The timber construction prizes represent consequently the quantitative biggest source of relevant construction projects.
Further, it is important to mention that there are no findings for the province of Vienna. Due to the fact that "Wienwood 05" had no repetition by now, there were no projects with the correct completion date, thus 2006 to 2012.
In addition, it is important to mention that a great number of innovative timber construction projects are already represented within this prize, which implicates repetitions of projects in other databases afterwards.

The results of the keyword search in the architectural databank **"nextroom"** in the diverse categories are below-mentioned in table 4.

Table 5: Results of the architectural databank "nextroom"

Category	**Result**	**Relevant**	**New of them**
Banks and stock markets	1	1	0
Educational and research facilities	22	19	8
Offices and administrations	7	7	3
Mixed utilization	12	9	5
Health and social services providers	8	7	4
Hotels and gastronomy	12	10	6
Industry and trade	6	6	3
Museums and exhibitions	0	0	0
Sport, recreation and recovery centres	15	13	9

Special constructions	5	4	3
Sum	**88**	**76**	**41**

During the databank research 88 timber construction projects have been found whereby 76 of them represent relevant construction projects for the case study analysis according to the above described methodology.
From 76 relevant construction projects, 41 have not been occurred in any other databases. 20 projects fall into the category “public building” and 21 into the category “commercial building”.
It is essential to mention at this point, that 35 timber construction projects have already been mentioned in other databases, most of them during the analysis of the timber construction prizes.

The results of the keyword search in the **“klima:akitv”** database in the diverse categories are listed below in table 5.

Table 6: Results of the “klima:aktiv” database

Category	Result	Relevant	New of these
Residential building	153	-	-
Public building	17	13	8
Commercial building	32	19	9
Renovation	6	-	-
Sum	**208**	**32**	**17**

The first analysis with the search item “timber construction” brought 208 results. 159 construction projects have been excluded due to the fact that they are residential constructions or renovation projects, both not relevant for the case study analysis. According to the methodology outlined above, 32 relevant construction projects could be collected during the research phase.
However, the number of additional construction projects was reduced due to increased overlap with other databases. From the 13 relevant public buildings, just 8 new projects have been added on the list. From the 19 “commercial buildings” 9 projects have not already been mentioned in another database.

The research results of the **state award of architecture and sustainability** are below-mentioned in table 6.

Table 7: Results of the state award of architecture and sustainability

Year	**Award winner**	**Nominations**	**Relevant**	**New of them**
2012	5	9	3	1
2010	4	10	7	2
2006	5	9	0	0
Sum	**14**	**28**	**10**	**3**

The nominations as well as award winners of the state award of architecture and sustainability 2006 were not considered due to fact that all nominations were built before 2006, thus accomplished in the year 2005 or earlier.
From the prize, awarded 2010, 2 findings have been considered, from that 1 in the category "public building" and 1 in the category "commercial building".
During the research of the nominations and award winners 2012, 1 "public building" project was gathered.

During the analysis of the research and technology program **"Buildings of Tomorrow"** guide, 11 projects have been considered for the choice of possible case studies.
10 of the selected projects are "commercial buildings" and just 1 of them is allocated to the category "public building".

In summery, after literature and database research, 192 relevant construction projects have been determined which are appropriate for the implementation of the case study analysis. The detailed findings are listed below.

Table 8: Number of timber construction projects from database research

Database	Public building	Commercial building	total
Timber construction prizes	67	53	120
Nextroom	20	21	41
Klima:aktiv	8	9	17
State award	1	2	3
Building of tomorrow	1	10	11

Sum	**97**	**95**	**192**

During the literature search in the timber journal “**zuschnitt”**, no further projects could have determined. All of the projects, described in “zuschnitt” have already been mentioned in another database before.

Before the implementation of the expert interviews, the extent of timber construction projects had to be reduced. The list of relevant projects was diminished to 26 projects after the selection criteria as described.
These 26 construction projects served as presented choice of innovative timber construction projects based on literature and database research (see appendix).

4.1.2.Expert interviews for determination of case studies

The initial list, consisting of 26 timber construction projects, has been extended with further innovative projects when mentioned explicitly by an expert. The final list consists of 29 selection projects (see appendix). Based on this list, the selection of the two case studies took place according to expert opinion combined with personal investigations.

First, construction projects unknown to experts have been removed from the list. Second, those projects, which have been familiar but not dedicated to any innovative category, have been eliminated as well.
Further elimination criteria were the emphasis and recommendations of experts, the gained information during the literature and database research as well as the setting of priorities, i.e. energy efficiency and comprehensive sustainability concept.

One public building was strongly recommended from experts several times and stands out due to its extensive sustainability concept as well as its constructive and architectural quality. There is talk of the community centre, St.Gerold, Vorarlberg, which was chosen as public building case study. The contracting entity was the community itself, which demanded highest standards of the architects, activities of craftsmen and everyone involved, concerning energy efficiency and sustainability.

The chosen commercial building was added subsequently on the list due to the explicit recommendation of three experts and its highly innovative characteristics.

According to the interviewed experts, the commercial building Life Cycle Tower One is “one of the most innovative timber constructions” in Austria or even in Europe. The building in question is one of the first multi-storey buildings composed of a timber-concrete hybrid construction in Dornbirn, Vorarlberg.

With the two determined case studies, both categories (public building and commercial building) are addressed and offer consequently varying framework conditions. Further, these differences are getting strengthened through different locations, such as countryside or urban area.

Nevertheless, beside the construction material timber the two construction projects have another similarity. Both are realized in Vorarlberg, the most western situated province in Austria.

Over the last few decades, Vorarlberg has become one of the most vibrant innovative regions for architecture. The special features of the local building culture are attributed to a rootedness in regional, especially craft traditions -keyword timber construction- and the early shift to ecological aspects of architecture. These qualities manifest themselves in public buildings, as well as in residential and commercial construction. Vorarlberg is recognized world wide for their pioneering role in this particular filed.

Its consistent further development of timber in the construction sector as well as its openness to new applications is remarkable and will be emphasised with the following two case study analyses.

4.2. Case study 1: Community centre St.Gerold

The first case study is a **public building** commissioned by the rural municipality St.Gerold in the “Großwalser Tal” (Great Walser Valey) in Vorarlberg. The public authority of St.Gerold acts as the contracting entity. This is done according to the “Vergabegesetz der Länder” (public procurement law of the provinces) and the “Bundesvergabegesetz”(Austrian Federal public procurement law) where the ÖNORM A 2050 “Procurement of works, services and supplies – Notices, tenders and award of contract – Procedural standard” is taken as a basis (BDB 2013).

Policy and society are faced with huge challenges relating to climate change, carbon emission, energy transition and usage of resources. Timber constructions can make a positive contribution towards a more sustainable lifestyle. Austria with its abundance of timber, timber construction traditions and recognized wood processing competencies could take a pioneering role, whereby the public sector would have to serve as a model. It’s the public sector´s part to reduce restrictions and prejudices by providing information, taken on responsibility and fostering innovation (Wiesner 2012)

4.2.1. Development stages St.Gerold

To determine and delineate precisely most essential actors and their role, cooperation and interaction, conflict solutions as well as impeding and fostering factors vital to the success, the project is divided in two main phases:

1. Development phase (incl. idea phase, preparation phase, planning phase
2. Realisation phase (production phase, completion phase)

This step was most helpful to have the ability to illustrate the process in full detail.

1.) Development phase

The development phase refers to specific activities with the primary function to discover and create new knowledge about social, economical or technological topics and/or find out new applications for the purpose of enabling development of a new product, process and/or service.

In the context of case study 1 this phase includes the requirement analysis, the structural survey and the two town meetings that result in a demand profile.
The development phase is subdivided in idea phase and preparation or planning phase respectively to assign respective tasks and activities to the varying actors and to achieve a maximum accuracy.

The **idea phase** represents the emergence of the project and clarifies questions about the initial situation before project launch. It deals with the question from where and/or from whom the idea for the building originates.
According to the major of St.Gerold, there was an absolute necessity of more space, equally for the municipality (= building promoter) and inhabitants (Interview Summer 2013).

The **preparation phase** describes necessary steps before the realisation of the community centre.
At this point it is important to mention that during the preparation phase it took place a fluent passage to the planning phase.
The **planning phase** includes the product-based, organisational, and strategic planning together with engineering and timing as well as clarification of legal, political and financial affairs.

In 2007, as a first step a **requirement analysis** (including essential, particular, as well as functional requirements) with the objective to guarantee an optimum use of space was prepared together with all parties concerned within the community. In the at that time used old school building, which is under monumental protection and without contemporary construction (energy concept) the requirements were not fulfilled.
As a second step, a **structural survey** followed. It was realized that a new building was necessary. During this step the ideal size and needed number of rooms were predefined.
After these processes the community reached agreement on a new community centre (Interview Summer 2013).

Concurrently the municipality started paying attention to other community centres, built in the region during the last few years. It is important to mention that diverse surrounding communities have built community centers of wood in recent years (for example the community center Blons or Raggal).

The objective of this activity was to learn from others mistakes and to benefit from those lessons learned during the construction and afterwards.
According to the mayor of St.Gerold it should be compulsory for public construction works to communicate with people who collected own construction experience (Interview Summer 2013).

Further important steps during the preparation and planning phase were the two town meetings, organized by the mayor where all interested and affected people were invited.
In 2008, very early in the development phase the **first meeting** was used to discuss upcoming construction plans and concepts to find out requirements, but also to collect ideas from the public.
In 2009, during the **second meeting** (at the end of the development phase), the mayor reported on the finished construction concept and the fixed architecture and public concerns were discussed.
These meetings were aimed to involve local people, discuss diverse options and to silence scruples.
Altogether, approximately 70 citizens (about one in five inhabitants) attended these meetings and made use of their participation in decision-making (Interview Summer 2013).

Between the two meetings, the representatives of the community prepared a **demand profile** (32-page) in cooperation with three environmental institutions.
This demand profile included, without limitation, an actual balance of community owned buildings, the requirement analysis, the structural survey, ecological requirements (low energy building, timber construction, and ecological materials) but also general demands like the redevelopment of the village centre (Interview Summer 2013).

In order to achieve the best architectural solution for the steeply sloping site on the main road, the municipality announced a competition, which was won by an **architectural bureau**, specialized on timber construction.
The competition was no usual open tendering procedure but rather a limited submission. The municipality argued against the usual procedure due to experiences of several neighborhood communities that in open tendering procedures it´s not possible to take into account and treat more than 100 project proposals equally.

For that reason, the municipality agreed on five architects in advance. With these five selected architects intensive discussion took place to decide who of them could realize best the community´s demands. These five got the 32-page demand profile and a plaster model according to the local and structural conditions. What was very uncommon was the payment of these 5 architects for their efforts to show the great significance of planning. A jury composed of vestryman finalized the decision.

The idea to build with wood has never been a discussion, but rather implicitness for the community (representatives + inhabitants). St.Gerold commands huge wood reserves from municipally owned forests, thus has regional and sustainable construction materials available. Other powerful arguments to build with wood were both the local value added that stays within the valley as well as the building tradition in the region.
Furthermore, the ecological perspective has been important since the very beginning and for that reason timber was eminently suitable.
From the major´s point of view, to build state of the art, ecology- minded and resource-efficiently was a basic prerequisite (Interview Summer 2013).

To sum up, all ideas and impulses originated locally, from the municipality in cooperation with the village population. In addition, the early integration of the architect and environmental institutes strongly influenced the idea generation during the research and development phase.

2.) Realisation phase

This phase represents necessary steps during the realisation of the project.
The realisation phase is subdivided in production phase and completion phase to assign respective tasks to the varying actors and to achieve a maximum accuracy as well.

The **production phase** is defined as the manufacturing process of the diverse parts and components of the building in the production hall and consists of the computer integrated manufacturing, the artisan production and includes the testing procedure of the diverse produced components.
In this case the whole production work of the construction components including the wooden furniture was made from two companies in the Valley.

The **completion phase** represents the conclusion phase of the project, thus the erection on site.
In 2008, the construction work of the first four-storey building made from wood in St.Gerold, Vorarlberg started under the lead management of St.Gerold´s major in cooperation with the architectural bureau Cukrowicz Nachbaur ZT, timber construction companies from the valley and other effected actors (see actors).

In 2009, the community center St.Gerold is completed, occupied and is used as a multi-purpose center including a kindergarten, a children´s game group, a village shop, a multi-purpose room and a local authority office (Interview Summer 2013).

4.2.2. The innovative aspects

An **innovative aspect from a technological as well as ecological perspective** arises from the consistent further development of a highly energy efficient timber construction right down to the last detail.
The compact volume is designed as a passive house (energy concept - see construction) and with regard to energy technique it is nearly self-sufficient.
Both, construction and facade are made from massive wood and mainly come from municipally owned wood whereas the floor, walls and ceiling are from trees grown in neighboring communities. The insulation and soundproofing is made of renewable and regional raw materials such as wood fibre and sheep´s wool.
Beside the decreased material cycles and embodied energy, the utilization of local resources creates **an innovative aspect from an economical and social perspective** as well. The major pointed towards an enhanced regional economy that generates and safeguards jobs and strengthens regional identity. The whole skilled manual work, such as the sawmill and joinery work, was carried out by companies located in the Valley. The traditional handling and short transport of the building materials ensure the sustainability of the material.
In addition, the wood used for the construction is inserted completely untreated and guarantees high spatial comfort and air quality through the almost exclusive use of local white fir (Abies Alba) (Interview Summer 2013).

An **innovative aspect from an organizational perspective** is the fact that the timber was felled in the winter and dried in the air to improve the durability of the wood. Furthermore, this process saves energy that is commonly wasted in the mechanical drying process of timber (Interview Summer 2013).

Apart from this, another **innovative aspect from an organisational as well as ecological perspective** arise from the consistent application of high-grade ecological materials.
All material was proved to all critical pollutants during the production process and its installation on site was monitored. It was aimed at avoiding hazardous waste through chemical management and at ecological optimization on the basis of the OI3 index.
The OI3 index describes the ecological quality of the thermal properties of the cladding and sub ceiling of a building. Evaluation criteria are:

- Amount of nonrenewable primary energy
- Acidification potential
- Global warming through greenhouse gases

The lower the OI3 value, the smaller the environmental burden originates from the building (Lipp 2006).
In addition all materials had to be free of PVC, H-FCKWs/HFKWs and other hazardous materials such as heavy metals in paints. Foams, silicon and materials with excessive packaging were not permitted either. The ecological guidelines were even adopted for electric piping and cabling.
According to the major of St.Gerold, this consistency in use of ecologically friendly materials should fulfill positive side effect concerning well-being and living quality (Interview Summer 2013).

4.2.3. The construction

The project is the first 4-storey timber building in Vorarlberg, completed 2009.
The four-storey solitaire is located at the steep sloping terrain on the south-facing slope of the Walser valley laterally shifted to the old school building that´s under monumental protection.
Together, these two buildings create a spatial gateway situation at the entrance to the village (Interview Summer 2013).
By general request of the inhabitants, a square with fountains, benches and trees was created in front of the entrance at street level, which not only serves as a car park but also as a village square creating a village center.
The object uses two existing even surfaces, the village square at street level as well as the playground level. It places itself as a connecting element in between that only two floors are visible from the street.

Figure 3: 4 storey perspective, south-west side, St.Gerold (picture: Hans Peter Schiess 2009, source Summer 2013)

Figure 4: Main entrance and newly created village square, east side (picture: Hans Peter Schiess 2009, source Summer 2013)

The new multi-purpose center houses a kindergarten, a children´s game group, a village shop, a multi-purpose room and a local authority office.

The various uses of the community center are spread over four floors. From the main entrance at the newly created village square, visitors get to the village shop selling regional farm products, and thus guaranteeing the local provision of usual goods. The top floor provides space for the local authority office and a multi-purpose room. Downstairs, at the foot of the building, there are the technology room, the kindergarten and children´s game group where an exit leads from the kindergarten directly into a playground sheltered from road traffic.

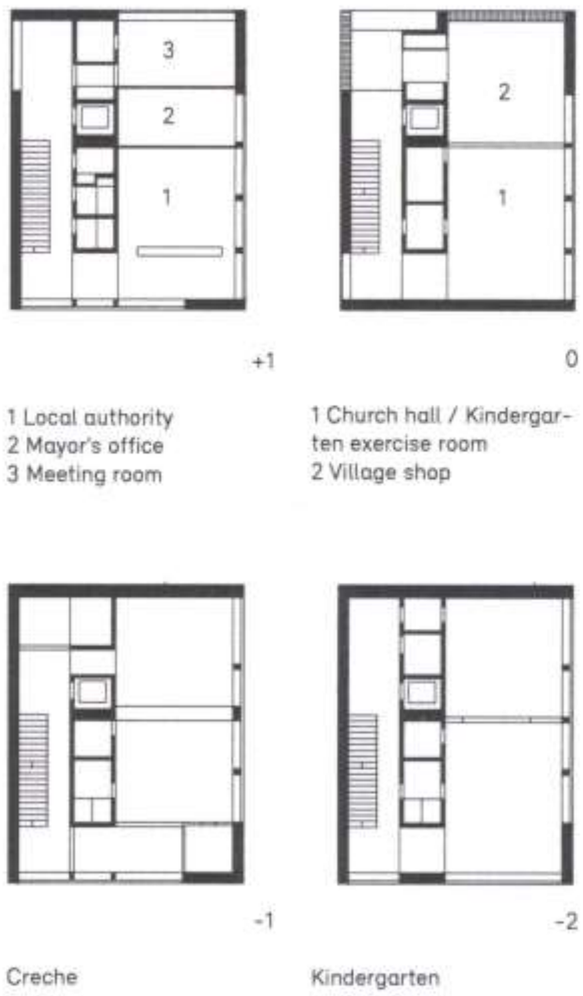

Figure 5: floorplan (source: Cukrowicz Nachbaur Architekten ZT GmbH 2008)

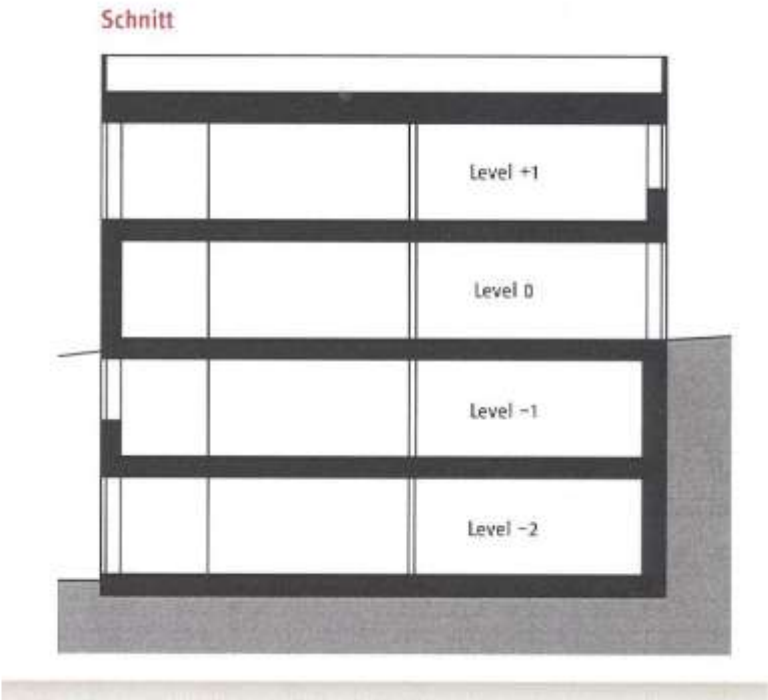

Figure 6: Section (source: Cukrowicz Nachbaur Architekten ZT GmbH 2008)

The white fir used in the construction and for the surfaces largely comes from the municipality's owned forests.
Primary structure and all components are realized with solid wood provided by municipally owned forests, only the supporting walls, touching the ground, are of reinforced concrete. The project is realized completely in wood, even the lift shaft, which ensures barrier-free access to the whole building, is made out of glued wood (Interviews Abbrederis 2013 Summer 2013).

Indoor, all surfaces are realized with untreated, domestic white fir.
Even the floors are made of rough-sawn planks that are cut with a slow moving saw, which gives them a typical pattern and a fine, furred surface. The floor feels like a wooden carpet and is extremely easy to care for.
The wooden furniture is largely integrated directly into the building and contributes to sustainability as well.
According to the architect, its clear, untreated wooden facade is a landmark for sustainability (Interview Abbrederis 2013).

Figure 7: Local authority (picture: Hans Peter Schiess, source Summer 2013)

Figure 8: Kindergarten (picture: Hans Peter Schiess, source Summer 2013)

Figure 9: Staircase (picture: Hans Peter Schiess, source Summer 2013)

A classic example for ecological buildings and domestic value creation like the community center St. Gerold also has to be sustainable in everyday life.
Thus, according to the interviewed architect and building promoter the building´s energy concept is important to mention.
It is constructed as a passive house with a low heating requirement of 14 kWh/m2a (according to the PHPP calculation). It is the first non-residential building in Vorarlberg, certificated by the Darmstadt Passive House Institute.
The energy concept includes a water/ brine heat pump with two geothermal probes (each one 160m) and a brine-earth collector under the base plate. The low hot water requirement can be completely covered by the heat pump. Further, the waste heat from the village shop´s cold stores is used as well. In summer the geothermal probe unit can be used for cooling (Interviews Abbrederis 2013 Summer 2013).

4.2.4. Involved actors and their roles

Based on the high ecological and energy efficient standard of the building that requires close contact throughout the entire project, table 8 shall give summary of the involved actors in the varying construction phases.

Table 9: Involved actors in the varying construction phases

Actors	Development phase		Realisation phase	
	Idea	Preparation/planning	Production	Completion
Building promoter= community	X	X	X	X
Inhabitants	X	X		
Architect		X	X	X
Research institutes	X	X		
Frame carpentries		X	X	X
Structural engineer		X	X	
District commission		X		X
Building supervision		X		X
Major of the neighboring municipality	X	X		

The **most important actor during development phase** was the **building promoter**, i.e. the **local council led by the mayor**. The mayor with his high ecological interests was most important concerning first ideas and impulses. Further, his contact and communication to the **mayor of a neighboring municipality** (that built a community center quite recently) influenced decisions on further involved actors.

According to the interviewed major of St.Gerold, to be in the ability to realize all these high ecological demands the municipality engaged the following three institutions

- Umweltinstitut Vorarlberg (Environmental Institute Vorarlberg)
- Energieinstitut Vorarlberg (Energy Institute Vorarlberg)
- and Spektrum

as consultants for ecological construction and ecologically sustainable procurement (Interview Summer 2013).

The **Umweltinstitut Vorarlberg** (Environmental Institute Vorarlberg), situated in Bregenz, is a citizen orientated center of competence and government department of the Vorarlberg state administration.
It is divided into two main areas of activity: food and environment.
Main tasks are permanent monitoring (e.g. emissions), environmental analysis, expertise, consulting and information with the aim to advertise profound knowledge of healthy food and the environment to the general public (Umweltinstitut Vorarlberg 2013).

The **Energieinstitut Vorarlberg** (Energy Institute Vorarlberg), situated in Dornbirn, is a friendly society with 40 employees. Its main area of responsibility is divided in four main topics: construction and living, renewable energy, electric energy and mobility. Its main tasks are subsidies, energy advising as well as research and education through various seminars, magazines and expert meetings. Main aim is the promotion of a more sensible use of energy, enhanced use of renewable energy, environmentally sound building methods and sustainable transport policies. It offers service regarding energy, energy efficiency and environmental building expertise appropriately for different target groups and provide impartial advice for users. The institute put emphasis on impartial information, networking, cooperation, innovation and synergies (Energieinstitut Vorarlberg 2013).

Spektrum, situated in Dornbirn, is an independent engineering office with 10 employees and center for environmental engineering and management. It offers service in all questions regarding construction physics and construction ecology and supervises whole construction projects from concept selection via planning through to implementation and quality management. Spektrum is in charge of all types of building but with a focus on “Nachhaltig: Bauen in der Gemeinde” (sustainable: constructions in the municipality) and public buildings (Spektrum, 2013).

The **architectural bureau** “Cukrowicz.nachbaur Architekten ZT GmbH” is specialized in timber constructions and gained experience due to its numerous realized timber construction projects in the past. The office was in the ability to fulfill perceptions and requirements best and won the municipality announced competition described above. The bureau won several prizes for their projects and is known for

their accurate work. Main task beside the architect´s plan was to react to the municipalities' wishes and to be open towards new ideas.
Further, the architect was main contact person concerning technical questions and an important source of knowledge concerning timber (Interview Abbrederis 2013).

From the major´s point of view it is important to mention the **inhabitants** of St.Gerold as well who participated high in number during the town meetings and contributed their ideas and scruples (Interview Summer 2013).

Due to financial and legal reasons the **district commission** as construction authority, the fire safety agency and the province Vorarlberg led by the governor were contacted during the preparation as well.
The **building supervision** was essential for legal technicalities and offered information concerning norms and standards.

During the **realization phase**, the number of professionals increased. Especially, the **architectural bureau** gained in importance with increased progress of the project. In addition a **structural engineer** responsible for structural engineering calculations completed the planning team.

Further important actors during the production and completion were two local **frame carpentries**, which were responsible for the production of the diverse wooden elements and components of the building. In addition, these two companies manufactured the whole interior furnishing as well.

4.2.5. Cooperation, interaction and information flow

According to the mayor of St. Gerold, the most important cooperation and information flow occurred between the mayor of St.Gerold and the mayor of Raggal, even beyond official appointments. (Interview Summer 2013).
The community Raggal, a neighbor community, had built a community center 2 years earlier and had caused a sensation with the construction regarding sustainability and served as a model for St.Gerold. The two mayors kept in close contact during the whole construction process where many discussions took place about further cooperation partners and steps, procurement of construction materials, lessons learned and general recommendations.

On recommendation of Raggal´s mayor, St.Gerold called for the same package of measures within the context of the international Interreg IIIA - project.
The Interreg IIIA - project stands for “ecological construction and procurement in community projects in the Lake Constance Region” and was a cooperation project between Austria, Switzerland and Germany. Aim of the cooperation project was the enhancement of comfortable and energy efficient buildings with ecological construction materials, thus being non-hazardous to health and environment and with small energy input during the whole product life cycle.
In the context of the Interreg IIIA projects, a field-tested information platform was developed concerning ecological construction with the objective to offer public contracting entities comprehensive support during planning and tendering procedure.

In addition, on recommendations received, a close cooperation took place between the three environmental institutions and St.Gerold, especially concerning selection of ecological construction materials.

Representatives on institutional level, except cooperation required by law and to clarify financial aspects, did not show interest before the completion of the project.
In regard to legal technicalities and information the interaction with the building supervision was essential during the start of construction works.

Further intensive cooperation took place between the mayor and the architectural bureau. The architect was next to the three advisory institutions an important source of knowledge. It was the architect´s responsibility to permanently incorporate all actors and to coordinate the craftsmen´s activities.
Taking account of craftsmanship and their knowledge as well as consider their way of looking at things was an important task of the architectural bureau.

A representative of the community managed the coordination of logging and provision of wood from the community´s owned forest in cooperation with the architect to evaluate the needed amount of wood.

Moreover, the communication with the inhabitants via two public meetings, as already mentioned, guaranteed the people´s contribution and acceptance. The mayor´s idea to connect the official meeting with a wine tasting as follow-up activity enhanced public participation and interaction – based communication (Interview Summer 2013).

According to the architect and the mayor of St.Gerold, the persistent and unrestricted information exchange between all affected people was a prerequisite for good results (Interviews Abbrederis 2013 Summer 2013).

4.2.6. Conflict management and problem solution

Every innovative construction goes with more or less serious conflicts, especially if a high number of participants are involved and many requirements have to be fulfilled.

Worth mentioning conflicts of interests occurred during the two public meetings with high civic participation.
The flat roof in such an alpine region gave rise to many discussions among the inhabitants.
Further, the untreated wooden floor was a highly discussed issue too. Missing knowledge and experience with this type of floor made inhabitants insecure. The typical pattern and fine, furred surface feels like a wooden carpet but seemed unconventional and hard to care for. In reality and in hindsight it is extremely easy to care for and people and users never want to do without it again.

The mayor of St.Gerold acted as the main conflict manager in every department. In case of the floor, he visited constructions with exactly the same floor as planned in the community centre and talked to the responsible cleaning staff to receive an impression of the floor´s features. At the second public meeting the mayor informed about positive experience by a majority of users and could silence scruples.
Especially in the case of the flat roof and other architectural peculiarities, the architect and the mayor explained their plans in detail and in cooperation with the public they weighed up the pros and cons. In addition, the architect and mayor offered their information and services at any time and beyond of public meetings. Through this behavior a disregard of inhabitants objections was avoided and the peculiarities obtained acceptance.
According to the architect and the mayor were no futher serious occurrences worth mentioning (Interviews Abbrederis 2013 Summer 2013).

4.2.7. Fostering and impeding factors

An essential fostering factor was the **intensive cooperation** between all involved actors. The openness with respect to innovation and ecological requirement had a beneficial effect. According to the mayor, without such a close interaction, information flow and personal effort such an outstanding project wouldn´t have been realizable (Interview Summer 2013).

In addition, the **financial support** from the province of Vorarlberg was a decisive factor for the realization of the community centre. At this point, it´s important to mention that neither the innovative modality of the construction nor the energy efficiency was a fostering factor in terms of the public funding. Important for the appropriation were just the liquidity and size of the community and the investment costs of the new building (Interview Summer 2013).

The fact that some neighboring communities had built in similar fashion in recent years had facilitated the whole process. The **benefit from other experiences and lessons learned** was pointed out several times by the mayor and architect and can be seen as a fostering factor.
According to the mayor those experiences save labor, troubles, time and money for future constructions (Interviews Abbrederis 2013 Summer 2013).

Another important fostering factor is the **clustering of timber construction experts**, companies and craftsmanship characterized by cooperation and consistent interexchange of new concepts, technologies, trends and developments. This clustering leads to an increased know how and a lively **building culture** as a consequence thereof. This high technical expertise and awareness combined with the long timber construction tradition makes Vorarlberg to a centre of innovation. The regional and local cooperation models like “Vai” and “Werkraum Bregenzerwald” make contributions to that culture as well.

Want of information was never the case or an impeding factor.

It was never the aim to arouse big attention through the construction, but the community was well aware of its liability towards its inhabitants, the next generation and the environment.
The **fundamental idea** of creating something special and the consistent further development of an ecological friendly way of construction was the most fostering factor.

From an organizational perspective, the procurement of ecologically friendly construction materials right down to the last detail was a major challenge and extremely time-consuming. The architect, the mayor and the three institutions had to put a lot of work into the search of suppliers who provide materials free of PVC, H-FCKWs/HFKWs and other hazardous materials such as heavy metals in paints.
Lack of experience with this kind of ecological selection criteria of products on both sides, the purchaser (architect, building promoter) and the supply firms was seen as impeding factor.
Due to the priority of ecological standards and conditions of the goods some suppliers and craftsmen had been overextended. According to the mayor, a need of explanatory work exists along the whole supply chain. Increased demand for environmentally friendly products of the public would facilitate the procurement in future and would lead to changes from a supply perspective (Interviews Abbrederis 2013 Summer 2013).

Framework conditions from a legal or political perspective were not seen as impeding factor. Although fire protection regulations got stricter over the last years, it was no impeding factor for the timber construction project. The contrary is the case. According to the architect, tighter regulations foster the construction with timber due to its controllable burning characteristics compared to steel.
Another point turning an impeding factor into a fostering one was the close cooperation and consequent information flow with the relevant fire protection authorities (Interviews Abbrederis 2013 Summer 2013).
Other noteworthy impeding factors were not mentioned according to the interviewed persons.

4.2.8. Evaluation of case study 1 and transferability

Although all interviewed persons mentioned an additional expenditure of time and increased cooperation effort in comparison with a conventional building, all involved parties emphasized their satisfaction with the result. Inhabitants and authorities are proud of their new wooden energy efficient community centre (Interview Summer 2013).

The mayor, the driving force behind the realization mentioned that without such a motivated and highly qualified team incorporating an information flow higher than-average, an innovative construction like the community centre St.Gerold would not have been possible.

Aside from the fact that St.Gerold´s unique geographical and topographical conditions are not transferable, Vorarlberg´s fostering framework conditions, old traditions and collected experience in regard to timber construction are favorable for innovations in this sector.
A one-to-one transferability was never intended and isn´t seen as useful in regard to varying standards and demands in each region and country (Interviews Abbrederis 2013 Summer 2013).

The project was awarded several prizes and awards. In 2010, the community centre St.Gerold won the State Prize of Architecture and Sustainability. Moreover, the project was also the award winner of the Timber Construction Prize Vorarlberg 2009 in the category "Public Building". Additionally, the project received an award at the 6.Vorarlberger Hypo Bauherrenpreis 2010.

Further awards and appreciations are:

- Energy Globe Vorarlberg 2009: validation of performance
- Piranesi Award 2009: validation of performance
- International Architecture Prize 2010
- Mies van der Rohe Award 2011: nomination

In addition, the community center St.Gerold was distinguished by Gold through the "Klima:aktiv" building standard (see 4.1.1.).

Based on publicity through several awards from national and international architectural awards, the feedback to and interest in the project was enormous and is unabated by now. Without any expenditure on advertising, people and authorities from the whole world (mainly Canadians, Japanese, Germans and Swiss) are visiting St.Gerold and want to learn about energy efficient timber construction (Interview Summer 2013).

However, the mayor and the inhabitants of St.Gerold are glad about further promotion of the principle of sustainability in the construction sector and want to demonstrate and offer both, policy makers and visitors', ecological possibilities and thoughts to take with them.

All involved parties see the community centre as a pioneering and important role model for other communities (Interviews Abbrederis 2013 Summer 2013).

4.3. Case study 2: Life Cycle Tower One (LCT One)

The second case study is a **commercial building** situated in the biggest city in Vorarlberg, Dornbirn. In comparison with case study 1, this construction shows considerable differences regarding its urban location, such as special requirements during the construction phase (noise annoyance, space requirement, etc.). Another important difference occurs through the kind of building owner, a private construction company. That implies that financial interests are more relevant with respect to two reasons: possible rental revenues through newly created office space as well as commercialisation of the newly developed modular timber-hybrid construction system (LCT system), used for the LCT One the first time. To be in the ability to compete economically with commercial constructions and as a result being marketable in the global market was a prerequisite for the LCT system.

4.3.1. Development stages of the Life Cycle Tower One

1.) Development phase

In the context of case study 2 this phase is equitable with the Life Cycle Tower research project.

Idea phase

According to the building promoter, at the beginning of the project there was the idea to expedite sustainability in the construction sector and nothing less than the desire to revolutionise the way of constructions (in regard to energy efficiency, CO2 balance, less waste, less noise, etc.), more precisely to develop a new kind of urban construction (Interview Zangerl 2013).

Although not yet specialised on timber construction in daily business, one of the managing directors of the building promoter´s company accepted the challenge to build the first multi-storey timber construction in an urban location in Austria.

Preparation phase

At this point it is important to mention that during the preparation phase it took place a fluent passage to the planning phase.

The **planning phase** includes the product-based,- organisational,- and strategic planning together with engineering and timing as well as clarification of legal,- political and financial affairs.

In **2009** the company Rhomberg Bau GmbH, who was the general contractor and building promoter later on, initiated the **Life Cycle Tower research project** together with an architectural office and a team of experts from practice.
A new construction system (LCT system), based on modular construction, that serves as basis for technical feasibility and is compatible with building standards as well as legal requirements had been targeted. Industrial prefabrication and planning focus on fire safety made the market readiness of the new product possible.
For the enforcing company conducting research was secondary, rather the realization of a demonstration building took top priority. The entire building system is oriented towards its technical and economically feasibility as well as ecological criteria.
The R&D project took 2 years time and targeted a submitted plan at a fictional location in Vorarlberg.
The LCT research project was supported by the

- "Österreichische Forschungsförderungsgesellschaft FFG (Austrian Research Promotion Agency), the
- BM:VIT (Ministry of Transport, Innovation and Technology) within the scope of the program "Haus der Zukunft Plus (Building of Tomorrow plus),
- and the "Raiffeisenlandesbank Vorarlberg" (regional bank) (CREE 2013; Interview Zangerl 2013).

In **2010**, during the LCT research project, the general contractor decided a **formation of a subsidiary company** (called **CREE**-Creative Resource and Energy Efficiency). Through the spin-off of the LCT research project, CREE has an exclusive focus on sustainability in the construction sector and the commercialisation of the LCT system.
Through exacting work on the details, at the end of the LCT research project the following results had been achieved

- An implementable building concept for construction, building technology and façade

- A wooden modular construction system (LCT system) as a new, independent product, which meets the requirements for fire protection, acoustics and load-bearing capacity
- An energy concept for a plus-energy-house
- A product and manufacturer neutral building technology-layout
- Ready to file planning for an imaginary location
- Lifecycle-oriented economical calculations
- A CO_2 balance and certification

under the lead management of CREE.

2.) Realisation phase

The realisation phase is subdivided in production phase and completion phase.

The **production phase** is defined as the manufacturing process of the diverse parts and components of the building in the production hall and consists of the computer integrated manufacturing, the artisan production and includes the testing procedure of the diverse produced components.

The **completion phase** represents the conclusion phase of the project, thus the erection on site.
In Sempeter **2011**, the construction work of a **prototype**, the first Life Cycle Tower, **LCT ONE**, an eight-storey demonstration building in Dornbirn, Vorarlberg began under the lead management of CREE in cooperation with the architectural bureau Kaufmann, the timber construction company Sohm Holzbau GmbH and various other effected actors (see actors).

In August **2012**, the **LCT ONE** is completed, occupied and used as office space. The first two floors are used as showroom and museum of innovative and energy efficient companies and products (called Life Cycle Hub).
The energy efficient building concept shall be tested with regard to its functional efficiency and real usage conditions. The demonstration project shall be presented to a wider public and shall illustrate the advantages of a batch-produced timber/hybrid high-rise building system to future investors and other interest groups and support market efforts. The system is intended for the international market.

In March 2013, the first fully commercial client project, Illwerke Zentrum Montafon (IZM) at Vandans, Vorarlberg was commissioned (CREE 2013; Interview Zangerl 2013).

4.3.2. The innovative aspects

The LCT One is the first prefabricated timber-hybrid multi-storey building with eight storeys in Austria.

Figure 10: LCT One, front view (source: Hermann Kaufmann ZT GmbH 2012)

Figure 11: Section (source: Hermann Kaufmann ZT GmbH 2012)

Innovative aspects from an economical perspective arise from the standardized modular elements produces off site the construction zone.

The decisive factor for a quick, flawless and neat work is the extensive prefabrication of structural elements (timber-concrete composite ribbed ceilings, façade elements) in the production hall that offers numerous benefits.
It ensures the construction process is independent from weather influences that may lead to repeated delays, resulting in higher costs found with conventional construction methods. It also provides optimal quality control and a high level of precision in detail.
The rapid assembly of prefabricated elements on the construction site is economical and contributes in limiting noise and dust emissions to a minimum.
Other considerable economic advantages compared to conventional multi-storey buildings are:

- lower life cycle costs
- reduced resource dependency
- security of costs and quality
- small area required during project execution and as a consequence less disturbances for neighbours and traffic
- positive image and pioneering role in ecological construction
- better carbon footprint (CREE 2013; Interview Zangerl 2013).

The limitation of construction components, a high degree of prefabrication and extremely short installation are just as much a characteristic of the LCT system as its flexibility in the building´s shape regarding façade and the energy standards. Variable applications (hotels, offices, apartments) through different architectural designs are possible.

An **innovative aspect from an ecological perspective** is the LCT One´s timber construction system that is distinguished by high resource efficiency.
This, on one hand is achieved by minimizing the use of materials in construction and on the other hand, by anticipating the future dismantling of the structure where the recycling of the building materials can also be guaranteed.
The ecological value of the LCT One is particularly evident when comparing the example of the LCT Ones ecologically defined values with these of a corresponding building that uses conventional construction methods (CREE 2013; Interview Zangerl 2013).

The relevant, nationally and internationally recognized Green Building certificates that the LCT One has received, are considered as semi-official seals of approval for the environmental quality of the building.

To sum up, the whole project opens up the opportunity to finally establish timber construction and its environmental qualities in urban areas.

4.3.3. The construction

The LCT system is a completely new developed overall concept.
In regards to construction, it rests on a structural skeleton with load distribution through a series of support points.
Its central elements are glued laminated timber columns, always arranged in pairs, and timber concrete hybrid slabs which are coupled together via sophisticated connections.
To simplify the construction process, the supporting columns can be integrated during the prefabrication of the façade elements.
Included among the special features of the LCT system is the permanent visibility of all load bearing timber components. This means that the aesthetic, tactile, organic structure and atmospheric qualities of the material remain fully preserved (Interview Dünser 2013).

Figure 12: Entrance area, (source: Herman Kaufmann ZT GmbH 2012)

Figure 13: Visible load bearing timber components (source: Herman Kaufmann ZT GmbH 2012)

From a technical perspective and key to success is the newly developed timber concrete hybrid slab, which represents the centrepiece of the LCT system.
It is composed of long rectangular shaped, prefabricated panel elements. These consist of four glulam beams (a double beam in the middle as well as a single beam at the outer edges) and an 8 cm thick steel reinforced concrete layer, which are connected together (Interview Dünser 2013).

Figure 14: Timber concrete hybrid slab (source: CREE 2013)

Reinforced concrete beams on the short sides of the slabs provide for, on the one hand, affixing beam heads. On the other hand they also serve, through vertical pipes embedded at the corners of the panels, as connection points to the structure.
The building´s service equipment is integrated between timber beams that are left visible. In addition, the timber concrete hybrid slab also plays a central role in strutting the whole construction, and acts as fire compartmentalization and sound insulation between the floors (Interview Dünser 2013).

The supporting structure provides a punctate load transfer across wooden columns. For this, columns are made of “Brettschichtholz” (BSH) (glued laminated timber). BSH consists of pre-sorted, defect free boards, which reconnected by means of finger jointing the length to lamellae. These are then layered together and glued to square timbers. Compared with solid wood, this results in various advantages: with the same cross section BSH has a significantly higher carrying capacity, thus enabling an economic use of materials. BSH also facilitates the planning process because this material is available in precisely standardized qualities in regards to its structural and optical characteristics (Interview Dünser 2013).

For a modular construction, a crucial factor is the connection between the building´s various elements. Connection between plate elements of the timber concrete hybrid slab and the BSH supports, or the core of the building, occurs via steel mandrels, which engage within steel pipes embedded in the plates. Immediately following installation, the steel pipes are cast with a fast setting material.
According to the architect, the solution developed here is characterized by simplicity and efficiency. It requires no elaborate preparation during prefabrication. It enables a rapid assembly of components on site. Finally, it guarantees a clean dismantling of the structure at the end of its life cycle, in order that the elements can be reused (Interview Dünser 2013).

The internal staircase was built with cast-in-situ concrete as opposed to suggestions originating from the previous research project LCT where the whole building was calculated and planned with wood, as well the staircase.
The massive construction of the staircase was the result based on an intensive examination of legal regulations regarding fire prevention. Although technically feasible, it is incompatible with present building regulations (Interview Dünser 2013).

Fire protection

Among the most persistent prejudices against timber construction is its alleged susceptibility to fire.
Regarding fire protection the LCT system meets the requirements laid down in numerous standards of fire safety, as well as a conventional construction.
The building´s fire resistance is based on a comprehensive approach that combines elements of structural and technical fire safety.
In the case of structural fire protection, it includes consistently preventing hollow spaces. Vitally important, however, is the timber concrete hybrid slab. An essential prerequisite for the fire prevention authority and for realisation was the test certificate (according to DIN EN 13501) concerning the fire resistance REI90 (F90) of the timber concrete hybrid slab. This eight centimetre thick concrete layer prevents the spread of flames from floor to floor for at least 90 minutes. Technical fire safety measures include the installation of fire alarms (Interview Dünser 2013).

Sound insulation

Timber construction also has to contend with old prejudice around the topic of sound insulation. The observance of standard acoustic performance quality is protected by a number of measures in the LCT System.
There is a classic method of reducing structure-borne noise to about that of a footstep: the insertion of mass, i.e. weight in the construction. In the LCT system the concrete layer of the timber concrete hybrid slab achieves this. In combination with false floors or floating floors, it ensures a minimization of sound transmission. Outside noise pollution is absorbed through the façade (Interview Dünser 2013).

Energy concept

Beside functionality, the aim of the energy concept was the realization of an indoor climate that is independent of usage. Both, working (office) and relaxing (hotel, apartments) shall be possible. At the same time, required energy use shall be reduced to a minimum. This requires a precise observation of all relevant energy fluxes and development of an integral energy concept.
The LCT One is built in passive house quality with heating requirement of 14 kWh/m2a. The entire energy concept is based on renewable resources. Hot water requirements can be covered by a solar thermal system and electricity is produced through photovoltaic cells on the roof, which feed surplus into public networks. Energy source for space heating and cooling is a geothermal heating with geothermal probes and a ventilation system with heat recovery (Interview Dünser 2013).

4.3.4. Involved actors and their role

Based on the high level of innovation that requires close contact throughout the entire project, table 9 shall give summary of the involved actors in the varying construction phases.

Table 10: Involved actors in the varying construction phases

Actors	**Development phase**		**Realisation phase**	
	Idea	Preparation/planning	Production	completion
Building promoter=general contractor	X	X	(X)	(X)
CREE		X	(X)	(X)
Architect	X	X	(X)	(X)
Planning team		X	(X)	(X)
Research institutes		X		
Testing institutes		X	X	X
Fire authority		X	(X)	(X)
Production companies		(X)	X	X
Funding institutions		X		X
Lobby (proHolz)		X		X
others			X	X

The **most important actor during the development phase** was at first the **general contractor**, who was at the same time **building promoter**.
According to the statement from the interview with a representative from CREE, the idea for such an innovative project had already existed a long time among the general contractor.
The Rhomberg Group is an international operating company that´s specialised on life-cycle and structure of buildings and is structured in its divisions for construction, railway technology (these departments are further sub-divided in various business fields) and resources.
The umbrella of this structure is the Rhomberg Holding, an independent family owned company and is managed by 2 general managers who are supported by an executive board consisting of four persons.

The Rhomberg Group has expanded step by step and has gradually added new business fields over time. In the construction & resources division 439 people are employed and in the railway technology division 484 people, in total 923 employees (458 in Vorarlberg). In the business year 2011/12, the turnover of the Rhomberg Group account for 350 Mio. € (Rail+Construction) incl. joint ventures. The Rhomberg group holds companies not only in Vorarlberg but all over the world. According to Rhomberg (2013), this financially sound basis allows "huge scope of innovative and perhaps even unconventional ideas. Important tracks are left only by those who cover new ground" (Rhomberg 2013)

As a big construction company, the Rhomberg Group aims at taking on responsibility for its planning concepts and building projects regarding its environmental impacts and engages oneself in resource,- and energy efficient constructions since many years.
This was the reason behind the formation of the subsidiary company CREE (Creative Resource and Energy Efficiency), located in Dornbirn, with the aim to specialize on natural change in urban architecture. By means of innovative strategies it is the main task of the 7 employees of CREE to reduce the resource,- and energy use during the entire life cycle of a building. Beside already well-established standards for energy efficient buildings, CREE concentrates on a consistent resource policy that analyses all system components for their ecological footprint and optimises when necessary. The Signa Holding, the RIMO Privatstiftung (private foundation) together with the Rhomberg Group are the majority shareholders.
CREE was responsible to take on all important tasks concerning the LCT One.
The newly established company was the co-ordination centre and assumed responsibility for the lead management. Bringing together architects, planners and authorities were essential for the integral planning approach. Further, the representation of the project to the outside and public relations are important tasks of CREE (Interview Zangerl 2013).

The **architectural bureau** involved from the start of the LCT research project, is specialist and advising on technical matters. The architectural office Kaufmann ZT GmbH is one of the most famous architects regarding energy efficiency and timber construction in Austria. The office has a reputation for combining the renewable resource timber with most efficient energy concepts and special local demands of customers. Its comprehensive experience with timber and its strenuous effort was essential for the whole project (Interviews Dünser 2013 Zangerl 2013).

To sum up, the building promoter and in this special case the newly founded subsidiary CREE together with the architect were the most influential and most active actors who put the rest of the team together.

Next to the usual actors (architectural bureau, building promoter, in house technician and construction physicist) the early inclusion and open communication with competent **supervisory authorities** was essential during the preparation and early planning phase. From the beginning fire protection authorities have been involved in the research as well as fire tests to meet requirements and to get authorizations granted in the end.
Permanent contact regarding changes, new test results and new ideas ensured best cooperation during the entire project (Interviews Dünser C. 2013 Zangerl 2013).

The **Federal Ministry of transport, innovation and technology** (BM:VIT) was supporting the project within the program “Haus der Zukunft Plus “ (house of tomorrow +).
Financial support was provided twice, first for the LCT research project and later on for the LCT One, thus its realization.
Further, the project achieved financial support from the “Österreichischen Forschungsförderungsgesellschaft” (FFG) (Austrian Research Promotion Agency) and from the “Raiffeisenlandesbank Vorarlberg” (regional bank) (Interview Zangerl 2013).

In addition, **pro Holz Austria** was interested in the project due to its innovative character. Pro Holz supported the LCT One project through marketing, promotion and online presence to reach the public at large.
Due to pro Holz´s extensive contacts in the timber construction industry, it assisted in searching for experts from practice to discuss mainly marketing topics (Interview Zangerl 2013).

Involved actors during realization phase have not changed essentially over time, rather more actors joined up with the existing team (Interviews Dünser 2013 Zangerl 2013).
The **“Institut für Brandschutztechnik und Sicherheitsforschung”** (IBS) (Institute for Fire Protection and Safety Research) is the largest testing and inspection agency for fire protection in Austria. As a state-accredited security service it was responsible for fire tests of materials, investigations and testing of products. Further it took over

tasks like inspections, reviews and assessments, necessarily for fire authority´s permission.
However, cross-border cooperation was still required concerning fire tests. According to the architect and CREE, there exists no research institute or company in Austria that´s equipped with a proper kiln (in terms of size). In order to be able to test the huge prefabricated wooden panels, the fire tests were implemented by the fire research institute Pavus in Czech Republic (Interviews Dünser 2013 Zangerl 2013).

Near implementation, more experiments in cooperation with **testing institutes** and authorities have been necessary to meet general requirements and to silence scruples.
According to Cree, public authorities gained influence and take on greater significance as the project progresses. During the research phase the permission of the authority isn´t yet needed, but later on (during production and final completion) mandatory (Interview; Zangerl 2013).

During the planning and production increased know how and mechanical skills have been adopted from the **timber construction company** Sohm Holzbau GmbH. According to the architect and CREE, new solutions originated through combining engineering science and knowledge with traditional craftsmanship (Interviews; Dünser 2013; Zangerl 2013).

Summarized, in regard to idea and preparation, at first the building promoter, later on the newly founded subsidiary company plus the architectural bureau were the most essential actors. Due to high order of innovation, in this case study many actors have joined up with the main team and assisted or contributed ideas during the development and implementation process. The relevant public authorities (fire protection authority Vorarlberg) and other actors involved during development and testing (Pavus Company in the Czech Republic, Sohm Holzbau- timber construction engineering) have played an important role as well.
For a successful realization of the Life Cycle Tower One, it requires interdisciplinary and cross-border cooperation (with the Pavus company).
It is interdisciplinary in the sense that it absorbs perspectives from different (technological science) disciplines, including timber construction and concrete construction, traditional handcraft and computer authorized production.
It requires cross-border cooperation in the sense that CREE tries to encompass all eligible testing institutes (Pavus company in Czech Republic).

4.3.5. Cooperation, interaction and information flow

An **integrated planning process** was applied to the entire project, which means that representatives of all areas of knowledge (architecture, static, facility management, building technology, etc.) had worked jointly through the essential tasks.
Exacting work on the detail and intensive cooperation is an absolute necessity for a trouble-free process.
Especially due to the project´s high order of innovation, it required meetings and information flow on a regular basis.
Regular workshops and meetings took place with the entire project team to present and discuss current information and results.
CREE, specially founded to represent the LCT One system to the outside, together with the architect´s team were the coordinators of all interactions, especially needed during labor-intensive working steps as planning.
Another central task of the team (CREE + architect) was carrying out theoretical simulations, which were checked and confirmed with real trials (e. g. fire test).
Further the team was responsible for the coordination of all tests and time management of these to guarantee a fluently progress of events (Interviews Dünser 2013 Zangerl 2013).

During the implementation phase of the construction, CREE together with the architect (project leader) took on the task of actors' coordination on the construction site.
Further, this team carried out negotiations and was responsible for the information flow with the relevant authorities (Interviews Dünser 2013 Zangerl 2013).

Like mentioned before, the involvement of production companies and craftsmen has been essential and contributed new ideas and solutions, mostly technologically and detailed solutions concerning modality.
Frame carpentry had direct influence concerning planning and development (Interviews Dünser 2013 Zangerl 2013).

The cooperation with public authorities was perceived as good, in particular the intensive interaction with the "Brandverhütungsstelle Vorarlberg" (fire protection authority) was mentioned several times from all interviewed persons. At first the responsible representative of the "Brandverhütungsstelle" was skeptical and very down on the project but was still cooperative and open. According to Zangerl (2013)

demotivating statements like “that´s not possible” have never been worded by anybody. The authority was unequivocal in support of new and innovative construction materials and processes.
During increased progress of the project, the representative has changed from a skeptic to a proponent of the project and he arbitrated between construction authority, building promoter and architect (Interviews Dünser 2013 Zangerl 2013).

CREE spoke of an information circular flow of developing, engineering and sampling that all involved actors have joined (Interview Zangerl 2013).

4.3.6. Conflict management and problem solution

Based on complexity, size and mass of novelties of the LCT One, several conflicts and complications occurred during development and implementation phase. The great number of involved actors and their strong cross-linkage implicates conflicts and divergences of opinion (Interviews Dünser 2013 Zangerl 2013).

During the whole research, testing and planning process, it happened that involved actors had no idea of how to solve special problems and what to do next due to missing experience and knowledge in a special field. In these situations the information was obtained from various experts from experience in whole Europe. CREE and the architect´s office extended the know-how pool continually, accepted new proposals for solution and implemented those and organized further testing scenarios in cooperation with testing institutes.
Due to the fact that calculated results often differ from results measured in reality, tests had to be repeated till they achieved required results. There was always a change between implementing, analysing and reacting.

Based on the cooperation from engineers and craftsmen, new creative solutions like the timber concrete slab have been worked out.
According to the architect, some problems such as special connections between modules and components were discussed several months on paper whereas the structural engineer in cooperation with the frame carpenter found a solution within a few days (Interview Dünser 2013).

From a technical perspective, the development of the ceiling construction was a challenge for the planning team, especially in regard to physical construction requirements (sound insulation and fire prevention see construction). New materials (wood composite) and constructions had to be developed and both, technical as well as economical practicability had to be tested (Interview Dünser 2013).
Further the team had to take measures that gave evidence of feasibility and fulfilled legal regulations.
A coordinated energy concept for such a large-volume timber construction had to be developed with special regard to the characteristics of the construction material wood.
According to the architect, there were no further technical problems due to the construction material wood. The key problem was always the fire prevention and to accomplish requirement for fire behavior (prerequisite was 120 minutes fire resistance of a ceiling cell) and to get permissions (fire certificate) of the authority in the end (Interview Dünser 2013).
In this case, breaking new ground was possible due to the inclusion of the approving authority plus fire brigade. The cooperation with these institutes was necessary to realize a holistic fire prevention concept (Interviews Dünser 2013 Zangerl 2013).

During the entire project it was important to think about possible consequences in advance to avoid interruptions and eliminate negative effects (in terms of costs and time). Due to missing experience, this was very time-consuming and involved actors had to put a lot of additional work into the project (Interviews Dünser 2013 Zangerl 2013).

There existed conflicts and differences of opinion between the general mangers of the building promoter company.
One of them, the initiator and proponent of the project, was absolutely convinced of the LCT One and its positive financial implications as well as effects on image. Other influential persons were skeptical of the pilot project, especially with regard to its feasibility and private financing. The budget was a recurring discussion within the building promoter.
The initiator always had to contend for the project to made realization, especially financing possible.
Enthusiasm not aroused until near completion when positive results were conceivable (Interview Zangerl 2013).

Further, the responsible representative of the fire protection authority had to resolve many divergences of opinion internally. Although the responsible person itself was skeptical at first, with increased knowledge and participation he has changed from a skeptic to a proponent of the project. The representative had to do a lot of persuading and know how transfer to reduce prejudices in regard to wood and fire prevention (Interview Zangerl 2013).

4.3.7. Fostering and impeding factors

An essential fostering factor was the **intensive cooperation** between all involved actors and experts. Due to complexity of the modular design it was necessary to have a good team working together since years. Frame carpentry, structural engineer and the architect´s office have had close business connections before the LCT project based on other realized projects in the past (Interviews Dünser 2013 Zangerl 2013).

Another important fostering factor is the **clustering of timber construction experts**, companies and craftsmanship characterized by cooperation and consistent interexchange of new concepts, technologies, trends and developments. This clustering leads to an increased know how and a lively **building culture** as a consequence thereof. This high technical expertise and awareness combined with the long timber construction tradition makes Vorarlberg to a centre of innovation (Interview Dünser 2013).

Further, the **tradition** to build with timber should not be underestimated as well due to a more positive and open approach with the material in principle.
The openness of authorities was motivating and fostering at the same time. In Vorarlberg, authorities carry out one´s task as a service provider where it´s possible to get necessary information quickly and non-bureaucratically. Without this service the innovation process would be difficult and frustrating due to lack of motivation, as well from a monetary perspective. Laborious visits of authority offices would slow down the planning enormously and complicate the whole planning phase (Interview Dünser 2013).

Another fostering factor was the **common fundamental idea** of creating a mould-breaking multi-story building, something really innovative and special regarding

ecological, technical, economical and social aspects. To be part of such a team and to speed up a sustainable development of the construction sector was a motivating factor. Act as a model for other construction companies.
But not just doing a good action was essential, rather **anticipated profit** and **increased market chances** due to the modular timber construction on a grand scale was beneficial for the realisation.
Another support for the ambitious project was the concomitant attention and media headlines (nationally and internationally), referable to the timber construction lobby like pro Holz Austria. The project was subject of many articles and covers without any marketing expenditure for the building promoter (Interviews Dünser 2013 Zangerl 2013).

The **financial support** from funding organisations, the BM:VIT within the project "Haus der Zukunft Plus" (Building of Tomorrow plus), the FFG and the "Raiffeisenbank" were essential as well. Although the financial support covered just a small part of the overall costs, it was an addition argument for realisation (Interview Zangerl 2013).

Excurse:
The project is supported from and part of the research and promotion programme "Haus der Zukunft Plus" (Building of Tomorrow plus), one of the Federal Ministry of Transport, Innovation and Technology´s research and technology programmes.
The long term vision of this programme is an increase in energy efficiency of building constructions and use to a point were the emissions of greenhouse gases over the entire life cycle of buildings are reduced to zero overall.
The programme "Haus der Zukunft Plus" has the prior goal to achieve technological preconditions for constructing buildings that do not consume energy, but generate it. Further it includes the creation of the technological basis for the building of tomorrow, especially the plus-energy house and supports the interlinking of key Austrian providers of know how internationally to boost the transfer of know-how across border.
The programme is focused on office and factory buildings, adapting innovative technologies and products for large-scale industrial manufacture as well as initiating demonstration projects to put new technologies and approaches on the map (Haus der Zukunft 2013).

Varying international, national as well as regional building regulations act contrary to development of a modular construction and timber construction in general.
In Austria, building law and regulations are task of the provinces, which entails nine different interpretations.
Although already harmonized by means of the "OIB Richtlinie" (OIB directive) to facilitate the construction process, additional expertise and reconfirmation of the LCT system is necessary in each province.
When acting according to the OIB directive one would imagine that there are no further permits necessary, but that ´s not reality (Interview; Dünser 2013).
Based on these still significant differences in legal regulations, it is not possible to guarantee approvability of wooden multi-storey buildings. Proof of concept is left up to each regional authority's discretion. Further, permissions of the authority depend on terms of use (hotel, office or apartment), which makes the whole **permissions process** even more complex.
All this facts are onerous conditions, but the actual situation in Austria (Interviews Dünser 2013 Zangerl 2013).

Another impeding factors were **prejudices and fears** of authorities, the public and other involved actors (supply companies) towards such an innovative project and wood in general. Lack of experiences and standardization as well as associated uncertainty were perceived as impedimentary. Due to the fact that the LCT One was a pilot project and various new developments occurred as a consequence thereof, period tests and increased communication had been necessary. Innovative pilot projects require **additional expenditure of time and money**. According to the building promoter, its team and the architect, they were fully aware of these extra efforts and expenses from day one, but still underestimated the extent of those facts (Interviews Dünser 2013 Zangerl 2013).

Lack of experience in the new technological solutions on the part of technical crews (heating installer and electricians) implied another impeding factor. According to the architect, they were overextended with some detail work and with the degree of complexity. High grade of prefabrication and increased interaction of varying actors calls for accurate construction work right down to the last detail (Interview Dünser 2013).

4.3.8. Evaluation of case study 2 and transferability

All involved actors and especially the building promoter are highly pleased with the result. The BM:VIT (on a national level), authorities, the mayor of Dornbirn (on a federal level) and neighbors are proud of the Life Cycle Tower One (Interviews Dünser 2013 Zangerl 2013).

However, it is important to distinguish two ways of feedback. On the one hand, there are journalists, the press and a great deal of attention.
According to interviewed actors, the project attracts public attention that was never experienced before (Interviews Dünser 2013 Zangerl 2013).
During the construction period more interested parties than construction workers were on site.
On the other hand, there should be possible customers who want to realize such buildings as well and are willing to pay money for it. By now more than 4000 people from the whole world, most of them Japanese and Canadian, visited the LCT One to learn about the system behind (Interview Zangerl 2013).

From the beginning transferability and international commercialization of the LCT system were essential requirements and absolutely targeted. Based on the modular design, varying scopes of architecture (various facades, flexible domestic engineering), different types of use (hotel, office, apartment) together with all the other ecological and economical advantages are indicative that transferability and repeatability is possible.
The LCT One is geared to international marketing and shall demonstrate possible applications of timber.
International know-how transfer was part of the project and will be strengthened in future through development of an international marketing, cooperation with international frame carpentries as well as further oral presentations and exhibition appearance.
At exhibitions there exists great interest, but mostly the additional effort in terms of time hampers interest and decline buying decision (Interviews Dünser 2013 Zangerl 2013).

From the building promoter´s standpoint the marketing of the LCT system focus on North American markets, Canada, Japan and Europe, where increased ecological

thinking leads to interest and rising investment in sustainable constructions like the LCT One.
Construction costs of the LCT system are slightly higher than those of conventional design but if considering the life cycle costs of a building (investment costs, running costs, removal costs) it is already more favorable (Interview Zangerl 2013).

Timber construction in urban areas is in the early stages of development (Interviews Dünser 2013 Zangerl 2013).
Despite great progress in fire prevention, in most countries the maximum height of timber construction is restricted, ranging from 3 to 6 stories and regulated by law. Just a few countries permit timber constructions above 8 stories.
This fact offers the problem that exceptional permission is necessary in most cities and countries although the LCT system is certificated according to the OIB directive. Further, whether or not a project is sustainable depends on the region and its special circumstances.
Every region is unique. What´s right on one place is not necessarily the best solution somewhere else (for instance a timber construction is doubtable in countries with less wood resources).
These arguments implicate an individual case assessment and case-by-case review depending on local requirements (Interviews Dünser 2013 Zangerl 2013).

Another argument against transferability are missing crafts and trades with needed know how in various regions and countries. Many construction companies don´t trust in their skills or don´t want to accept a risk of such an innovative building.
For that reason increased know how transfer is already implemented and will be important if transferability is targeted. To compensate missing know how, the newly founded subsidiary company CREE offers various services, from lead management of the whole project to render assistance and support during implementation (CREE 2013; Interview Zangerl 2013).

Based on the prototype LCT One the building promoter can provide written evidence regarding imperviousness, speed and dryness and weather protection during the construction phase. Further, people receive measured values from the demonstration building because everything is measured and controlled automatically.
The system can be brought to series-production with the help of the test results.
The particular challenge lies in the industrialization of the entire construction process. This comprises planning processes, batch production of the modules, fitness for

purpose, logistics and construction, which can be tested using the demonstration object and optimized for large-volume constructions (CREE 2013; Interview Zangerl 2013).

In addition, all involved actors gathered experience during the implementation of the LCT One and are willing to share their knowledge.
Now, after successful realization of the prototype, for the involved actors, it´s possible to see improvement actions and carry out optimization measures for future constructions. Right now, the building promoter together with the architect are working on several improvement activities to be able to reduce costs, which will make it more profitable and more attractive for future investors (Interviews Dünser 2013 Zangerl 2013).

In the mean time, another project, Illwerke Zentrum Montafon (IZM), built with the LCT system with nearly the same constellation of actors (identic architectural bureau, same executive construction company) is in the finalization phase (CREE 2013; Interview Zangerl 2013).
The IZM, a hydro-electric power competence centre, is one of the largest offices realised with a timber-hybrid construction system in Europe, the investment costs account for about 30 Mio. Euro.
Based on an architectural competition, the architectural office Hermann Kaufmann ZT GmbH, together with CREE with their LCT system won the bid. The decisive factors were the energy concept (Passive House Standard), the innovative and sustainable timber-concrete concept (IZM 2013) and the short realisation phase on site.

4.4. Findings of the case study analyses

4.4.1. Involved actors and their role

In both case studies, the respective **building contractors** were initiator and driving force throughout the project.
In the beginning their role was to draw up the outline of the project and to determine ecological, architectural and other requirements essential to them.
Further, the roles of the building contractors were not restricted to provide funds, rather more they were strongly integrated in each phase of the project. Most important tasks were the willingness to assist in any situation, render mental work and contribute ideas.

Next to the building contractor, in both case studies the **architects** played a central role during the whole innovation process.
Both case studies have in common that the architectural bureaus are specialized on timber constructions and acquainted with the material wood, thus gained necessary experience over the last years.
The architects were the most important idea generator and knowledge carrier concerning timber. The knowledge as well as the technological mastery of timber is very essential, especially in projects with such a high degree of innovation.
Additional, the architects took on the task of the interface and were responsible for the disclosure of information to all involved and affected actors.
Further tasks of the architects were the coordination of operating cycles, delegation of authority and to stay on top of things.
There is also the fact that based on missing expertise and experience from other actors regarding planning with timber, the architects had to fulfil increased technical tasks in addition to the creative work.
Further, based on the high degree of innovation, the engagement in legal requirements (norms, building laws) was higher than average.

Based on their production knowledge and solid craft, the **timber construction companies** played an important role as well through advising on technical matters and in supporting the architects regarding engineering.

The **professional institutions (research and testing institutions) and federal government** were involved since the development phase to clarify on the one hand concessions (authorisation) and on the other hand appropriation (subsidies).

Business environment and technical framework conditions were imposed by the **provincial government** (in both cases from the province Vorarlberg). Most essential regulations and requirements (such as building regulations, subsidies policy, flame- and fire-proof arrangement etc.) concerning the construction sector fall within the province´s remit.

4.4.2. Cooperation, interaction and information flow

According to the interviewed actors, they made use of a new way of cooperation, which is marked by higher than average information flow.

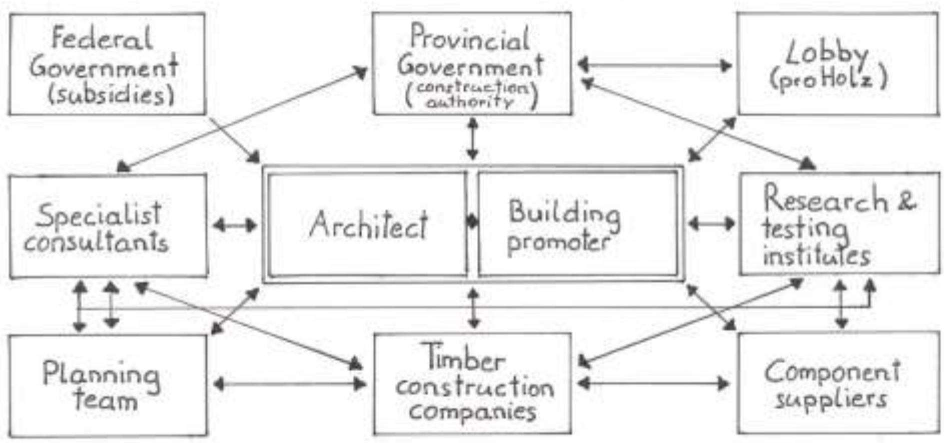

Figure 15: Complex information flow during the innovation process (own illustration)

First, both case studies were determined by an integrated planning process, which means intensive exchange of knowledge and information amongst all involved and affected actors throughout the whole development, -planning,- and realisation phase. Further it means that all actors met each other on the same level, from the architect to the construction worker.

Second, during the development and implementation phase both case studies were characterized by the interaction between the architects, the building promoter and the traditional craftsmanship.

Frame carpenters and timber construction companies worked hand in hand with the main actors. The timber construction sector´s solid craftsmanship or so-called "old knowledge" is indispensable and may provide the basis for further steps that facilitate inventions and innovations.

According to Dünser (2012), the ability to invent and produce tradable innovative buildings increases when huge construction enterprises or general contractors and small craft enterprises are equal partner who find engineering design and energy efficient building solutions in cooperation.
There is talk of a new method of manufacturing based on cooperation with collective aims instead of private profit. This encourages mutual assistance, mutual support and motivation as well as cohesion in a region.

Third, all development and construction progresses were communicated on a regular basis. Thus, the team composed of the architect and building contractor hold meetings where most important actors and those affected were invited to discuss progress, problems and new solutions.
In projects with such a high number of actors and the high degree of innovation, several repetitions of diverse actions and feedback-loops were inevitable. However, they could have been minimized trough increased cooperation, interaction and information flows.

From the interviewed experts´ point of view these open and integrated cooperation processes made the difference compared to common construction processes.
The actors' spoke of an open circuit of information flow composed of the main players (architect, building contractor, timber construction companies) that were expanded by specialist consultants (research-and testing institutes, authorities, etc.) when required.
This new way of cooperation was the key success factor and an innovation itself.

4.4.3. Conflict management and problem solution

Every innovative construction goes with more or less serious conflicts, especially if a high number of participants are involved and many requirements have to be fulfilled. The great number of involved actors and their strong cross-linkage implicates conflicts and divergences of opinion.

Kaufmann H. (2011,42) refers to the construction process as “unorganized chaos” because the assembly and fitting of the majority of building elements still happens on the construction site. Framing, domestic engineering and fit out are realised in sequence and independently of each other but not across the trades. Further, unforeseen events or/and inappropriate weather conditions lead to commonly occurring disturbances on site. Already finished building components are partially damaged through subsequent craftsmen or insufficient shelter against the weather. All these factors may lead to conflicts between involved actors and to construction defects.

To be in the ability to avoid these emerging conflicts it was important to think about possible consequences in advance to avoid interruptions and eliminate negative effects (in terms of costs and time). Planning and regulation right down to the last detail helped to avoid unforeseeable events.
Further, increased cooperation and information flow was essential to avoid conflicts. The inclusion of all affected actors was a key component and made sure transparency and sense of responsibility in varying areas of accountability.
In both case studies the architects in cooperation with the building promoters were most responsible for conflict management and problem solution and offered their information and services at any time and beyond of official meetings.

Innovators who want to open new perspectives and possibilities have to accept new challenges and have to resolve conflicts like described in the case studies.

4.4.4. Fostering and impeding factors

In the following chapter, the most important fostering and impeding factors of the two case studies are described and summarized. Due to the fact that commercial and public constructions are build for different reasons and varying motifs, distinctions and commonalities regarding fostering and impeding factors are obtained in detail.

Fostering factors

A number of common and varying fostering factors have been determined (cf. table 10).

Table 11: Fostering factors

	Public building	Commercial building
Common fostering factors	Intensive cooperation between all involved actors	
	Tradition & Experiences with the construction material timber	
	Joint project of creating something special regarding social, ecological and economical aspects (sustainable thinking)	
	Financial support (subsidies)	
	Advertising & Publicity (attention)	
	Clustering of timber construction experts	
Varying fostering factors	Local pride and awareness	Open up new market chances
		Anticipated profit

The table above shows that most fostering factors concerning the timber construction process are the same whether from the public or the commercial sector despite their varying motifs for the buildings.

Intensive and well-working **cooperation between all involved actors and experts** has been mentioned several times during the interviews and was perceived as extremely positive and inevitable for building processes that target innovate constructions of the future.

In the interviews with the experts it became clear that both **tradition** with the building material timber and already gathered **experiences** over the last decades have been perceived as fostering factors. To build with timber became almost implicitness for customers as well as architects. According to the building contractors of the two case studies, the preference of the domestic construction material timber has two main reasons. On the one hand it is based on the woodiness of the region and on the other hand it is the people´s awareness and pride of their own timber construction culture.

Further, both innovative buildings share the underlying idea of influencing the building construction sector in a sustainable and resource efficient way.

The involved actors spoke of a **joint project of creating something special regarding social** (cooperation, increased quality of life), **ecological** (energy efficiency, choice of materials) **and economical** (regional value added) **aspects.**
It was a powerful fostering factor to have the feeling of being part of a team that has the ability to change resource depletion in the construction sector.
According to the interviewed actors the environmental awareness was a strong motivation and was an overriding principle.

Another collective fostering factor is that both received **financial support** in the form of subsidies from public funds. For both public and commercial timber buildings with such a high degree of innovation is it very important to be subsidized by the State. Without financial support, buildings with such an intensive research, development and planning phase are hardly possible. For instance buildings like the LCT One are just realizable as a result of financial cooperation between economics (in this case a general contractor) and politics (BM:VIT, FFG).

Public attention was in both cases higher than average not at least because both won several prizes and awards, including the “Holzbaupreis Vorarlberg” (timber construction prize) and were present in many professional journals.
According to the interviewed actors, such concomitant **advertising and publicity** were not expected, but welcome and indeed a fostering factor. Due to the high ecological quality of the community center, interested people from Austria and worldwide are visiting the small community and create in this way extra income. In case of the commercial building, strengthening ecological image of the company and their products is seen as a positive ancillary effect.
However, the building contractors of both case studies are persuaded that just energy efficient and sustainably produced constructions will have influence on the construction market in future. They are proud to represent their buildings and solutions in public and to share their experiences, information and knowledge.

Clustering of timber construction experts through local cooperation models can be seen crucial as well. Both architects are members of “Vai” (Vorarlberger Architektur Institut) where cooperation and consistent interexchange of new concepts, technologies, trends and developments is lived. This exchange leads to increased creative expertise and construction quality. As a consequence, Vorarlberg has a building culture characterized by a combination of old tradition and new expertise with a view to valley interests and energy efficiency.

A fostering factor that differed between case study 1 (public building) and case study 2 (commercial building) refers to the local sign of case study 1 in comparison to the market orientation of case study 2. In St.Gerold, the local public support from the citizens was crucial. In case study 2, to o**pen up new markets** at national and international level and **anticipated profit** through active marketing measures of the new product (Life Cycle Tower system) were main aims throughout the project. The newly founded subsidiary company CREE is depending on further orders and receipts of the LCT system.

Impeding factors

The following impeding factors have been determined (cf. table 11).

Table 12: Impeding factors

	Public building	**Commercial building**
Collective impeding factors	Increased organisational effort for innovative solutions	
	Additional expenditure of time and money	
	Varying building regulations across countries	
	Lack of experience and standardisation for wood as building material	
	Prejudices & fears regarding use of wood	
	Suppliers, craftsmen and technical crews had been sometimes overextended	
Varying impeding factors	-	

The table above shows that the interviewed building contractors regardless of whether from the public or commercial sector have perceived and mentioned the same impeding factors.
Technical difficulties have not been mentioned as impeding factors. Specific technical topics like fire prevention, soundproofing or moisture penetration have been considered as a challenge and could be solved through specific planning right down to the last detail.

Nevertheless, this accurate planning including many tests as well as the intensive cooperation with many feedback loops was **an increased organisational effort**.

Further, all interviewed actors were fully aware that innovative buildings with such high quality standard imply **additional expenditure of time and money**. However, according to the building promoters, financial expenditures were better assessable than the additional expenditure of time. From the building contractors point of view that´s the case because costs are on one´s own responsibility whereas additional time is hardly manageable, mainly based on trade-spanning activities and lack of experience.

Based on the fact that the case studies were built in the same province Vorarlberg both were faced with the same business environment. Due to the fact that Vorarlberg boast an old tradition regarding timber constructions, current timber building regulations are kept up to date. Architects have learned to work according to fire protection regulations and other regulations.
However, in the case of the LCT One and the commercialization of the LCT system on a national and international level, **varying building regulations** in Austria are impeding factors. In general, both case studies are hardly applicable to other provinces in Austria due to varying regulations and missing standardisation.

Although both architect offices are specializing in timber constructions since years, they still mentioned **lack of experience and inadequate standardisation** as impeding factor. This is mainly because every bigger timber construction is still a prototype and standardisation does not yet exist. Further, from the viewpoint of all interviewed actors, it is hardly possible to have enough experience especially concerning constructions with many novelties.

Although Vorarlberg has tradition and experience with timber constructions **prejudices and fears** were mentioned from at least three interviewed actors. From an architect´s point of view, information, communication and cooperation are most essential to distract people´s fears. It is generally agreed that successfully realized constructions like the “Gemeindezentrum St.Gerold” (community centre) or the LCT One make a contribution to reduce prejudices regarding timber constructions.

As a last point, an impeding factor mentioned from all interviewed actors several times was the cooperation with varying effected actors, like for instance suppliers, craftsmen or technical crews (installers, electricians). Those actors had been overextended in some situation due to missing experience.

4.4.5. Need for action

It was generally agreed that there exists a long overdue revival and “need for action” in the construction process in general as well as in the timber construction process.

In all discussions, the interviewed actors charge that at the present time nearly every (big) timber construction (except single-family houses) is a prototype, the current structure of the construction industry doesn´t allow anything else.
But to obtain more planning security, quality of execution as well as permission certainty, an increased **standardisation concerning legal requirements** (building regulations, fire prevention, sound insulation, etc.) is required all over Austria.
Also related to standardisation, the interviewed expert´s opinions are that commonly, norms, standards and regulations should fulfil the task of helping and supporting actors to rely on facts and to simplify, thus to speak a uniform language. However, from a present-day perspective the interviewed architects addressed repeatedly the time-consuming search for the appropriate norms, which makes up a large part of work time whereby time for creative work decreases as a natural consequence.
According to the interviewed experts the increased standardization and simplification of building law regarding the timber construction sector will be inevitable in near future.

Another important point that requires need for action is the attitude towards cooperation with other companies and experts, on national and international level.
From the viewpoint of the interviewed experts, an increased cooperation not only between varying actors or companies respectively of the timber industry is important. They call for **more cooperation and less competitiveness** between different construction sectors (steel industry, concrete industry, brick building sector, etc.) as well.
The aim is the combination of both, varying people and different expertise as well as different materials and components, thus, the breakup of occupational barriers and bringing together all affected actors.
To find optimal solutions and develop innovations in common for a more sustainable way of living are main reasons of this need for action.

The new way of interacting with information, data and machines call for an interdisciplinary cooperation, from the architect and building promoter via the executive companies through to assemblers.
According to the building promoter of the LCT One, such pioneering buildings are only possible through a mixture of construction materials instead of the common static view of classical separation of materials. In the case of the LCT One, technical difficulties regarding fire prevention were resolved through this new approach, thus through a timber-concrete-hybrid construction.

However, not only the negative attitude towards cooperation is an important need for action, the **elimination of prejudices** is essential as well.
There still exist typical negative associations (fire prevention, sound insulation and so forth) when talking about timber constructions. Most people associate automatically the construction material wood with fire.
Although they decline in frequency it is important to do not spare the open discussion and to address honestly the disadvantages of timber constructions compared to massive constructions. It is better to compensate these disadvantages through intelligent planning instead of argue them away.
In the meanwhile the timber construction branch has solid arguments to allay fears not least because its fire behaviour is more assessable and manageable compared to most other construction materials.
Over the last years engineers have been successful in improving fire safety, earthquake, and soundproofing of timber walls and sub ceilings.
Many old, “unbreakable” rules and sceptics concerning for instance the height of timber construction are convinced of the contrary.

To sum up, transparency, innovative implementation approaches, open book solutions, creativity and cooperation instead of destructive business practices and gridlocked prejudices are required.

4.4.6. Trends and challenges for the timber construction

A trend that slowly but steadily is in the mind of people (both architects and customers) is **energy efficient as well as sustainable constructions.**

In the interviews with the experts it became clear that in consequence of foreseeable resource depletion there will be increased pressure and demand for resource optimized construction in future, regardless of whether public or private sector.
As a renewable, carbon-neutral, domestic and universal construction-material at once, timber can contribute to a more sustainable and worth living architecture in both urban and rural areas.
Further, based on its several possibilities of untreated application, timber represents naturalness and can help to increase indoor quality, thus enhance quality of living and indoor environment quality in constructions.
These facts make the usage of timber to an important partner for a sustainable development in the construction sector that focus on humans and society is in accordance with nature, technology and culture without neglecting economical necessity.
No other construction material shows such comprehensive energy efficiency, thus positive climate impact, as wood (Wegener 2012, 16).

Another interesting trend is the fact, that in future more and more general contractors and **huge construction companies** will be concerned with the topic timber construction due to enhanced market demand for resource saving construction possibilities.
However, the structure of the timber construction industry consists mostly of traditional craftsmanship, small and medium-sized frame carpentries are the majority in Austria. In most cases, these small frame carpenters are not able to raise funds for modern machines or provide funds for R&D.
All interviewed actors concluded that in future, an increased number of big construction companies will undertake the duty of R&D and will create innovations regarding possible timber materials or applications.
Great potential lies in a more intensive cooperation between actors with traditional knowledge and actors of general contractors with the required machinery and research funds.

Not entirely new but definitely an economic trend is the increased **prefabrication** of construction elements and timber is amongst all construction materials that material with best preconditions. Due to its special characteristics, such as good machinability, low weight and especially low transportation weight, the relocation of production from the construction site to the workshop is easily possible.

Prefabrication offers an alternative option as against common building processes on construction site.
From the architects point of view, not the uniform modular unit (thus standardized dimension of construction components), but rather the intelligent classification of component ties and material compositions will be a criterion for economical production.
The modular construction with its typical prefabrication makes technical and organisational standardisation without the assumed/expected unification possible.
According to the interviewed architects and experts, the optimization of the construction process seems to be linked to the degree of a building´s prefabrication.

Since lately, another aim of future oriented construction companies and architects is to plan buildings in that way to be in the ability to separate constructions or building systems at the end of their life cycle, thus to recycle or reutilise already used building materials.
The consideration of the entire life cycle of a product or material respectively during the planning, development and implementation phase is already in existence and will getting more important and will gain more attention in future.
Timber has mentionable advantages towards other construction materials in this case as well.
According to the architect of the LCT One, lawmakers will make multiple utilization including recycling of products compulsory in future. The architect justified his statement based on resource depletion, increased (construction) waste, less building sites and growth of population.
In both case studies the entire building is seen as a comprehensive process that starts with the idea generation to daily use to demolition.

Another trend that shows up in the timber construction sector is the construction of **multi-storey buildings**.
An example is the “Bridport House”, London, England, a residential building with 8 storeys.
The highest multi-storey timber construction (residential building) in the world till now was realized in Melbourne, Australia with 10 storeys.
In Milan, Italy, the highest multi-storey timber building (9 storeys) of Europe is near completion, which is realised as residential building as well (proHolz, 2013).

In the construction branch, the multi-story constructions is deemed to be the ultimate challenge, although its existence arise mainly from enlarged effective surface and space-saving requirements instead of main human needs.
Typical features of timber like its low weight and its easy machinability combined with computer-based product technologies predestine it for huge constructions like the LCT One.

However, it is important to call superiority of timber into question in each project and bring into question advantages and disadvantages instead of pushing boundaries at any cost.
A positive point is the fact that through extreme implementations long overdue discussions arise and offer affected actors a favourable opportunity to challenge many prejudices in terms of structural physics or technological matters.
In addition, extraordinary applications of timber will foster improvement and encourage further research & development.

5. Summary and outlook

By use of two innovative timber construction projects in the categories “public building” and “commercial building”, this thesis analyses innovation processes in the energy efficient timber construction in Austria. For that purpose main actors and their role, the cooperation and interaction process, conflict management and problem solving as well as fostering and impeding factors have been analysed. Additional questions regarding need for action as well as future trends and challenges in the timber construction sector have been examined.

Both case studies have in common that these building types have never been realised in the present form before. Case study one is the first four-story timber construction in passive house standard in Vorarlberg while case study two is the first eight-storey timber hybrid building in Austria. Experts in course of the study have selected them as the most innovative examples for the categories of public and commercial building.

Compared with the master thesis of Schwarz (2009), the number of institutions, training centres and clusters, dealing with energy efficient timber constructions as well as the participating in public prizes have increased over the last 4 years which confirms the positive trend of increased and forced networking.
It is conspicuous that main actors and their role have not changed remarkably when compared with Winch´s (1998) theory. Another similarities are the cooperation higher than average between all involved actors as well as increased organisational effort and as a consequence additional expenditure of time.
Evidently, it seems that impeding factors like planning uncertainty based on missing standards have decreased, at least in Vorarlberg. The involved persons didn´t perceive the cooperation with the institutional system as difficult or inconvenient, quite contrary to Schwarz´s case study in Vienna.
Another positive advancement is the fact that in the meanwhile the OIB directive came into force in all provinces in Austria, which creates a sense of consistency in the construction sector in the nine provinces. However, it seems that prejudices and insufficient experience regarding timber have improved far too little and are still the most impeding factors.

Innovation system and processes

The delineated case studies confirm with Hirsch-Kreinsen and Jacobson (2008) and Fagerberg (2005) that the innovation process is not a linear but rather a systematic process. This is a consequence of many varying actors involved but not least because timber construction cannot be considered separately. Rather it has to be seen in a broader context of other building technologies and sectors. The more aspects of a complex system are considered, the more likely are results and prospects of success.

Consentaneous with Czerny et al. (2010), Nord et al. (2011) and Winch (1998) successful innovations in the timber construction sector are a matter of very complex processes, involving a set of private and public actors as well as policies.

When considering **most important actors**, the architects and the building promoters with their role as driving force and decision makers are worth mentioning.

The building promoters were mainly responsible regarding first ideas and impulses, the initiators of the projects. Their role was much more than to provide funds, rather their commitment for the realisation of the projects was most important.

The architects are specialists regarding timber construction and are rich in know how and experience concerning the construction material wood.

Based on this experience they made available technical know how and together with the timber construction companies they were main knowledge source concerning technical matters. The efficient and well working cooperation of these most important actors (building promoters and architects) was definitely crucial to the successful outcome of the case studies.

From the beginning the role of representatives on institution level was not only confined to financial affairs and legal technicalities rather they were integrated into the team and into the process like described in Nord et al. 2011.

All other involved actors showed information flow higher than-average as well and had to put additional work and time into the project.

The cooperation process can be described as a persistent and unrestricted interaction and information exchange between all affected people throughout the entire project.

To present and discuss current information and results with the entire project team regular workshops and meetings were organized by the architects.

New solutions have originated through combing engineering science and knowledge with traditional craftsmanship.

The early involvement of all affected actors such as research institutes, the timber construction companies, the public and representatives on institutional level was seen as a chance to get at new ideas and solutions and ensured improved transparency.
The architects and building promoters were mainly responsible for the coordination of this intensive cooperation.
To sum up, the cooperation process can be described as an information circular flow that all involved actors have joined. As such, innovation is essentially a learning process among different actors.

Regarding the **problem solution or conflict management,** the architects in cooperation with the building promoters acted as main conflict managers.
Every innovative construction goes with more or less serious conflicts, especially if a high number of participants are involved and many requirements have to be fulfilled. These facts and the actors' complex cross-linkages implied exact planning right down to the last detail to minimize unnecessary feedback loops, mistakes and conflicts. During the entire project it was important to think about possible consequences in advance to avoid interruptions and eliminate negative effects in terms of costs and time. However, there occurred less problems or conflicts as expected, most interpersonally and not technologically.

Fostering and impeding factors

When looking at **the fostering factors** the intensive cooperation between all involved actors throughout the whole project stands out and is considered as the most important fostering factor. Based on the efficient information flow, involved actors had the ability to benefit from other involved people´s experiences and as a positive result saved labour, time, conflicts and money.
Another essential factor was the old tradition and experience with the building material wood in Vorarlberg that has created confidence among expert and other involved people.
Further the clustering of timber construction experts and regional cooperation models such as “werkraum bregenzerwald” and “vai” can be seen as crucial.
The common fundamental idea of creating something really special in the sense of “green buildings”, thus the consistent further development of an ecologically friendly way of the construction process and being role model were definitely positive incentives. Financial support was helpful regardless of whether public or commercial building, but was not the most decisive factor in the presented case studies,

especially not in the commercial building. In the case of the commercial building the aim to open up new markets as one of the first providers of such a timber hybrid system was most fostering.

When summing up **the impeding factors,** the increased organisational effort of the main actors (architects, building contractors) due to additional planning, testing and lack of experience were major challenges and extremely time-consuming. Framework conditions from a legal or political perspective were not seen as impeding factor during implementation phase. The contrary was the case. Although both fire protection - and ecological standards got stricter over the last years, the tightening of standards was not perceived as impeding factors because timber construction systems are in the ability to conform to these standards already.
Another point turning an impeding factor into a fostering one was the close and efficient cooperation and consequent information flow between architects, building promoters and legal institutions such as the relevant fire protection authorities. It seems that Vorarlberg has a pioneering role in this respect. In case study two, where commercialization is targeted in other Austrian provinces and European countries as well, varying building regulations and less experience and as a consequence prejudices and increased organisational effort and additional expenditure of time are still impeding factors.

Innovations

Sustainable development of the construction sector requires a fundamental change of resource utilisation through **innovations in many aspects**. Thereby it is important to consider technological, organisational, ecological as well as institutional aspects to get a holistic view.

In case study one, the most essential **technological innovation** is the uncompromising use of timber right down to the last detail from the building envelope via the elevator shaft trough to the wooden furniture and the wood floor. In case study two, the most important technological innovation is the timber concrete hybrid slab, thus the entirely new combination of these two different building materials. Just because of this combination of materials the LCT system is in compliance with the requirements regarding sound protection and fire prevention. Another technological innovation is the modular concept and as a consequence its versatility as office building, hotel or any other asked use.

From an **organisational perspective** the most essential innovations are the open cooperation from all involved actors as well as the enhanced involvement of local companies and citizens. The human is faced with enormous challenges when thinking about climate change or financial crisis and those are just solvable if many people work together intelligently.
Another organisational innovation is the high degree of prefabrication in the production hall and as a result the quick construction on site that offers economic advantages regarding security of costs and quality.

The most **important ecological innovations** are the saving of CO2 based on the increased use of timber as well as the energy efficient domestic engineering system with renewable energies exclusively. The consistent use of ecologically compatible construction materials entails reduced environmental burden through minimized waste products and reusability after operating life.
Both case studies are good examples regarding resource efficiency, recycling, reusability, decreased emissions as well as energy efficiency in daily use.
The decreased resource requirements in the entire lifecycle, the decreased material cycles as well as the abandonment of hazardous products show that through selective measures in the production process an energy efficient and sustainable construction might very well be possible.

From an institutional perspective and because it is no implicitness in Austria, the efficient cooperation, open communication and knowledge exchange between the architects, buildings promoters and the main institutional actors are worth mentioning. The case studies show that in order to realise highly innovative buildings, it may be necessary to adopt public regulations and/or an appropriate interpretation of existing law. Interestingly, it is not a requirement to loosen the strict fire protection regulation in order to foster timber construction. Rather, strict prescriptions seem to speak for timber. However, there is a strong need for an adequate assessment of timber construction.

Considering **trends and challenges** there is observed a clear trend towards energy efficient as well as sustainable constructions regardless of whether public or private sector.
Based on the enhanced market demand for resource saving construction possibilities, more and more general contractors and huge construction companies will be concerned with timber construction in future.

The consideration of the entire life cycle of building components is already in existence and will getting more important as well. Especially in this respect timber has mentionable advantages towards other construction materials due to its reusability and recycling management (Kuittinen 2013).
An important economic trend is the improvement and further development of prefabrication of construction elements and timber is amongst all construction materials that material with best preconditions.
Another emerging trend in the timber construction sector is the construction of multi-storey buildings although it is deemed to be the ultimate challenge in the construction branch.

The described impeding factors and future challenges lead to **need for action** in the timber construction process. To obtain more planning security, quality of execution as well as law certainty, binding standardisation concerning building regulations seems to be required all over Austria in the view of the involved actors. At least the acceptance and compulsory introduction of the OIB directive in all nine provinces is a step in the right direction.
According to interviews building law (norms and regulations) lag far behind latest developments and are only able to make reference to already existing technologies and processes. As a consequence and to keep laws up to date the increased inclusion of the legal institutions is of particular importance.
Another important point that requires need for action is the attitude towards cooperation with other companies and experts and especially with different sectors (steel industry, concrete industry, brick building sector, etc.). The aim is the combination of both, varying people with different expertise as well as different materials and components, thus, the breakup of occupational barriers and static views of classical separation of materials.
Further, the elimination of prejudices along all affected people and typical negative association (fire prevention, sound insulation and so forth), when talking about timber constructions, require need for action as well.
In the meanwhile the timber construction branch has solid arguments to allay fears not least because of the fire behaviour, that is more assessable and manageable compared to most other construction materials.
Many old, “unbreakable” rules and sceptics concerning for instance the height of timber construction are convinced of the contrary by the delineated cases.

Outlook

At the present time the timber construction sector benefits from an increased demand for more energy efficient and ecologically friendly products from both, customers and producers.
This ecological trend as well as stricter building codes, requirements and subsidies regarding energy efficiency and non-hazardous materials are a strong motivation for innovations in the construction sector in general and offers great market potential for the timber construction in particular. And most important, timber is in the ability to offer already market solutions.
In Austria already every fourth construction project realized by the public was built with timber in 2008. The public sector and organisations working for the community implement timber construction with increasing frequency (Zuschnitt 46, 2012).

Timber comes back into fashion and has the ability to fulfil justified demands regarding ecological and price efficient constructions due to prefabrication as well as an old and solid craftsmanship and tradition.
With the aid of timber and timber products, a great quantity of energy and carbon dioxide emissions can be conserved which means less energy consumption and through this active climate protection.
It is an extremely multifaceted and multipurpose material that has an unbeatable low environmental impact and can be a vital component to originate reasonable fundamentals for an energy transition in the construction sector. Timber constructions have definitely great potential when refined creatively and intelligently.

However, there exists still untapped potential in timber construction sector, especially when it comes to networking.
Based on the complexity of the innovation process, synergies and closer partnerships with experts and other construction sectors will get more important for planners and companies. Timber-hybrid construction systems, like the LCT One system, are in many cases very efficient construction systems and create further fields of application, especially in urban areas.
Instead of destructive business practices and gridlocked prejudices, in future transparency, open book solutions, creativity and cooperation is required. A huge range of duty for research and development will come up, which just can be solved through enhanced cooperation of a team of experts and all involved actors in common. It needs networking on regional, national as well as international level to find access to knowledge, inspiration and resources. And especially important but

often neglected is the improved internal communication with the whole project staff to be in the ability to support each other.

The performance ability of timber constructions was demonstrated impressively by innovative projects in recent years. As a consequence the impression is created that timber constructions have the ability to solve all problems of the building of tomorrow. Thereby, timber is simply over challenged. Not everyone, who will use the ecological material will use it with sense but rather will try to participate trends without much effort.

The construction industry misses the point when using as much timber as possible. An honest comparison of advantages and disadvantages will be necessary. It should not be the aim to imitate or copy typical steel- and concrete constructions at any price.

Almost everything is possible, but not everything makes sense, neither from an ecological or economical perspective nor from an architectural view.

Another critical factor to realise ideas and implement them in successful innovations is the motivation. Successful entrepreneurs are those who are determined to reach a long-range objective with major importance for them (in the two case studies climate and environment protection and conservation of resources in the construction sector).

It´s interesting that behind both described projects enthusiastic individuals- persons with visions, motives, power to convince and remarkable endurance - have managed the whole project. An innovation or idea is like a stage play: it needs a good producer and a good promoter. Otherwise the first performance will never happen or will be cancelled after a week due to lack of public interest. Rather it needs skilful marketing to change people´s perceptions and manners, especially, when the idea starts to question ingrained habits.

Like impressively shown by the two represented projects, not technological possibilities were most impeding factors, but rather the insufficient imagination, experience and knowledge concerning the construction material timber.

To change a system, in this particular case the construction industry, means to change attitude, expectations and behaviours as well as eliminate prejudices, doubt and fear. The two case studies should serve the purpose that future timber construction projects are faced with less prejudices.

Conforming with Nord et al. (2011) the detailed description of outstanding projects is one possibility to show how change and innovation works and has the ability to give others inspiration. Success stories have to be told!
As a result it is of great importance to realise showcase projects despite all emerging risk.
Innovations require outcomes and real projects because those are still in the ability to arouse strong media and public attention across the globe.

The two described projects are neither the only solution nor the end of development regarding energy efficient timber constructions, but they show a possible next step towards a more sustainable future in the construction sector.
At the moment new cultures of cooperation meet technological achievements never seen before, both interact and in this way create an impressive momentum of exciting product, process and organisational innovations.

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Interview partners for the Case Studies

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Dünser C., 26.02.2013. Architectural project manager of the LCT One.
Summer B., 27.02. 2013. Major of St.Gerold.
Zangerl M., 26.02.2013. Press officier of CREE.
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Appendix 1: List of selected construction projects after database research, prepared for the expert interviews for determination of case studies

No.	Name	Province	location	Build year	Short information
1	Einkaufszentrum Sutterlüty	Vbg	Hohenems	2010	HBPreis Preisträger 2011, lokales Holz, vorgefertigte Holzelemente
2	Raiffeisenbank Mittelbregenzerwald	Vbg	Egg	2010	HBPreis Preisträger 2011: Heimische Wertschöpfung, Passivhausstandard, einer der ersten 4-geschossigen Holzbauten Vorarlbergs, heimische Weißtanne
3	Eine Welt Handel AG	St	Niklasdorf	2009	HBPreis Nominierung 2011, Staatspreis für Architektur & Nachhaltigkeit Nominierung 2010, Passivhausstandard, Holzmodulbausystem (EU Projekt Holiwood), klima:aktiv GOLD
4	Bürogebäude Mayr Melnhof	St	Leoben	2008	HBPreis Preisträger 2009, firmeneigene Produkte wie Brettschichtholz und -sperrholz
5	Umweltkompetenzzentrum Wechselland Schäffern	St	Schäffern	2008	HBPreis Nominierung 2009, Sonderpreis Nachhaltigkeit beim HBP 2009, Passivhausstandard, innovative Deckenkonstruktion - Kielstegsystem (TU Graz), klima:aktiv Gebäude
6	Weingut Heike & Gernot heinrich	Bgld	Gols	2008	HBPreis Preisträger 2012
7	Biomasseheizwerk	S	Farchen	2010	HBPreis Auszeichnung 2011, Passivhausstandard, 4 verschiedene Bausysteme vereint
8	Fachhochschule Salzburg	S	Kuchl	2009	HBPreis Auszeichnung 2011, Passivhausstandard, Architekturpreis Land Salzburg 2010-Anerkennung
9	Werkstättengebäude binderholz	T	Fügen	2007	HBPreis Auszeichnnung 2011, hauseigene BBS-Fertigteile, Fichten - Brettsperrholzelemente
10	Intersparmarkt	K	Klagenfurt	2011	HBPreis Auszeichnung 2011
11	Technikzentrum Holzbauwerke E.Roth Gmbh	K	Feldkirchen	2008	HBPreis Auszeichnung 2009, Landesbaupreis 2008, wärmeisolierende Massivelemente, eigens entwickelte Massivholzwand

12	Büro & Produktionshalle Weissenseer	K	Greifenburg	2009	Holzriegelkonstruktion, Passivhausstandard, Klima:aktiv GOLD
13	Weinviertler Museum	NÖ	Niedersulz	2012	HBPreis Preisträger 2012, Aussenfassade aus alten Dachbodenhölzern, Passivhausstandard, Stoh=Dämmung, innovative Fassadengestaltung
14	Naturfreundehaus Knofeleben	NÖ	Reichenau	2012	HBPreis Preisträger 2012, Insellösung (energieautark)
15	TechCenter	NÖ	Unterradlberg	2011	HBPreis Preisträger 2011, Holzrahmenbau-Konstruktion, Modulbauweise (hoher Vorfertigungsgrad), überwiegend eigene Produkte, Passivhausstandard
16	Büro,-Schulungsgebäude LK/FIH Ried	OÖ	Ried im Innkreis	2009	HBPreis Auszeichnung 2009, Naturholz
17	Gemeindezentrum Raggal	Vbg	Raggal	2006	HBPreis Auszeichnung 2007, Nominierung zum Staatspreis für Architektur & Nachhaltigkeit 2010, 6.Vorarlberger HypoBauherrenpreis 2010 Auszeichnung
18	Gemeindezentrum St.Gerold	Vbg	St. Gerold	2009	HBPreis Preisträger 2009 + Passivhauspreis, erster 4 geschossiger Holzbau Vbgs, 1. Passivhauszertifizierter öffentlicher Bau Vbgs, Klima:aktiv Gold, Staatspreis für Architektur & Nachhaltigkeit 2010
19	Feuerwehr +Kindergarten	Vbg	Thüringerberg	2010	HBPreis Preisträger 2011, heimisches Fichtenholz, 3 Schicht -Holzfaserplatten, Passivhausstandard
20	Kindergarten V	NÖ	Guntramsdorf	2010	HBPreis Preisträger 2011, internationale Zertifikat in Silber der Österr.Gesellschaft für Nachhaltige Immobilienwirtschaft
21	Kindergarten Großrust	NÖ	Großrust	2010	HBPreis Nominierung 2011, Pfosten – Riegelkonstruktion, klima:aktiv GOLD, Passivhausstandard
22	Weinlandbad Mistelbach	NÖ	Mistelbach	2009	HBPreis Preisträger 2009, Bauherrenpreis der ZV 2009, Brettsperrholzplatten

23	Agrarbildungszentrum Salzkammergut	OÖ	Altmünster	2011	HBPreis Auszeichnung 2012, Sonderpreis für Energieeffizienz & reg. Wertschöpfung, heimische Weißtanne, Passivhausstandard
24	Gemeindezentrum und Tourismusbüro	S	Kleinarl	2009	HBPreis Auszeichnung 2011, Brettsperrholzelemente
25	Kinderkrippe Schönbrunngasse	St	Graz	2010	HBPreis Preisträger 2011, Nominierung Architekturpreis des Landes Steiermark 2010, vorgefertigte Holzelemente, Passivhausstandard
26	Kultur,-Veranstaltungszentrum	T	Absam	2010	HBPreis Auszeichnung 2011, Auszeichnung des Landes Tirol für Neues Bauen 2010, Nominierung Bauherrenpreis der ZV 2010

Appendix 2: List of selected construction projects after database research, prepared for the expert interviews for determination of case studies

No.	Name	Province	location	Build year	Short information
1	Einkaufszentrum Sutterlüty	Vbg	Hohenems	2010	HBPreis Preisträger 2011, lokales Holz, vorgefertigte Holzelemente
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3	Eine Welt Handel AG	St	Niklasdorf	2009	HBPreis Nominierung 2011, Staatspreis für Architektur & Nachhaltigkeit Nominierung 2010, Passivhausstandard, Holzmodulbausystem (EU Projekt Holiwood), klima:aktiv GOLD
4	Bürogebäude Mayr Melnhof	St	Leoben	2008	HBPreis Preisträger 2009, firmeneigene Produkte wie Brettschichtholz und -sperrholz
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6	Weingut Heike & Gernot heinrich	Bgld	Gols	2008	HBPreis Preisträger 2012
7	Biomasseheizwerk	S	Farchen	2010	HBPreis Auszeichnung 2011, Passivhausstandard, 4 verschiedene Bausysteme vereint
8	Fachhochschule Salzburg	S	Kuchl	2009	HBPreis Auszeichnung 2011, Passivhausstandard, Architekturpreis Land Salzburg 2010-Anerkennung
9	Werkstättengebäude binderholz	T	Fügen	2007	HBPreis Auszeichnnung 2011, hauseigene BBS-Fertigteile, Fichten - Brettsperrholzelemente
10	Intersparmarkt	K	Klagenfurt	2011	HBPreis Auszeichnung 2011
11	Technikzentrum Holzbauwerke E.Roth Gmbh	K	Feldkirchen	2008	HBPreis Auszeichnung 2009, Landesbaupreis 2008, wärmeisolierende Massivelemente, eigens entwickelte Massivholzwand
12	Büro & Produktionshalle Weissenseer	K	Greifenburg	2009	Holzriegelkonstruktion, Passivhausstandard, Klima:aktiv GOLD
13	Weinviertler Museum	NÖ	Niedersulz	2012	HBPreis Preisträger 2012, Aussenfassade aus alten Dachbodenhölzern, Passivhausstandard, Stoh=Dämmung,

					innovative Fassadengestaltung
14	Naturfreundehaus Knofeleben	NÖ	Reichenau	2012	HBPreis Preisträger 2012, Insellösung (energieautark)
15	TechCenter	NÖ	Unterradlberg	2011	HBPreis Preisträger 2011, Holzrahmenbau-Konstruktion, Modulbauweise (hoher Vorfertigungsgrad), überwiegend eigene Produkte, Passivhausstandard
16	Büro,-Schulungsgebäude LK/FIH Ried	OÖ	Ried im Innkreis	2009	HBPreis Auszeichnung 2009, Naturholz
17	Gemeindezentrum Raggal	Vbg	Raggal	2006	HBPreis Auszeichnung 2007, Nominierung zum Staatspreis für Architektur & Nachhaltigkeit 2010, 6.Vorarlberger HypoBauherrenpreis 2010 Auszeichnung
18	Gemeindezentrum St.Gerold	Vbg	St. Gerold	2009	HBPreis Preisträger 2009 + Passivhauspreis, erster 4 geschossiger Holzbau Vbgs, 1. Passivhauszertifizierter öffentlicher Bau Vbgs, Klima:aktiv Gold, Staatspreis für Architektur & Nachhaltigkeit 2010
19	Feuerwehr +Kindergarten	Vbg	Thüringerberg	2010	HBPreis Preisträger 2011, heimisches Fichtenholz, 3 Schicht - Holzfaserplatten, Passivhausstandard
20	Kindergarten V	NÖ	Guntramsdorf	2010	HBPreis Preisträger 2011, internationale Zertifikat in Silber der Österr.Gesellschaft für Nachhaltige Immobilienwirtschaft
21	Kindergarten Großrust	NÖ	Großrust	2010	HBPreis Nominierung 2011, Pfosten – Riegelkonstruktion, klima:aktiv GOLD, Passivhausstandard
22	Weinlandbad Mistelbach	NÖ	Mistelbach	2009	HBPreis Preisträger 2009, Bauherrenpreis der ZV 2009, Brettsperrholzplatten
23	Agrarbildungszentrum Salzkammergut	OÖ	Altmünster	2011	HBPreis Auszeichnung 2012, Sonderpreis für Energieeffizienz & reg. Wertschöpfung, heimische Weißtanne, Passivhausstandard
24	Gemeindezentrum und Tourismusbüro	S	Kleinarl	2009	HBPreis Auszeichnung 2011, Brettsperrholzelemente
25	Kinderkrippe Schönbrunngasse	St	Graz	2010	HBPreis Preisträger 2011, Nominierung Architekturpreis des Landes Steiermark 2010, vorgefertigte Holzelemente, Passivhausstandard
26	Kultur,-Veranstaltungszentrum	T	Absam	2010	HBPreis Auszeichnung 2011, Auszeichnung des Landes Tirol für Neues Bauen 2010, Nominierung Bauherrenpreis der ZV

					2010
27	Life Cycle Tower	Vbg	Dornbirn	2012	Erstes 8 stöckiges Holz-Hochhaus in Österreich, Systembauweise, hoher Vorfertigungsgrad, Passivhauskonzept
28	Gemeindezentrum Lorüns	Vbg	Lorüns	2012	Klima:aktiv GOLD, Passivhausstandard, regionale Holzmaterialien
29	Kommunalzentrum West, Flughafen Wien	NÖ	Schwechat	2011	Tragstruktur: 28,5m fischbauchförmige Holzleimbinder, Brettschichtholz + vorgefertigte Wand- und Dachelemente

Appendix 3: Experteninterview zur Festlegung der Fallbeispiele

Allgemeine Angaben

Interviewpartner:

Organisation:

Datum:

Beginn:

Ende:

Dauer: 30 Minuten

Titel: Innovation processes in the energy efficient timber construction in Austria

Vorstellung und einleitende Erklärung

Im Zuge meines internationalen Masterstudiengangs " Natural Resources Management and Ecological Engineering" an der Universität für Bodenkultur, Wien, in Kooperation mit der Lincoln University, Neuseeland, schreibe ich am Department für Wirtschafts- und Sozialwissenschaften, speziell am Institut für Wald-,Umwelt-und Ressourcenpolitik an der Masterarbeit zum Thema „ Innovation processes in the energy efficient timber construction in Austria".

Das Institut für Wald-, Umwelt- und Ressourcenpolitik beschäftigt sich politikwissenschaftlich mit Prozessen, Instrumenten und Institutionen in den Themenbereichen Wald, Umwelt und natürliche Ressourcen. Die Masterarbeit erfolgt im Rahmen des laufenden Projekts CO2 effizientes Bauen mit Holz gefördert durch den Fachverband der Holzindustrie Österreichs unter der Projektleitung von Dipl.-Ing. Dr. Gerhard Weiss.

Die Masterarbeit beschäftigt sich mit Innovationen in der energieeffizienten Holzbaubranche und speziell in den Bereichen „Öffentlicher Bau" und „Gewerbebau", errichtet in Österreich im Zeitraum 2006 bis 2012. Es soll mittels ausgewählten Fallbeispielen der Innovationsprozess im Detail analysiert werden und mit Hilfe von Experteninterviews mit beteiligten Akteuren und Organisationen eine Fallstudienanalyse durchgeführt werden. Im Zuge dessen werden das Bauprojekt allgemein, die wesentlichen Akteure, fördernde und hinderliche Faktoren sowie deren Interaktion im Detail beschrieben werden.

Ziel der Befragung
Es sollen innovative Holzbauprojekte aus den Kategorien „Öffentlicher Bau" und „Gewerbebau", jeweils ein Bauprojekt per Kategorie, für die Durchführung einer Fallstudienanalyse ermittelt werden.

Hinweis zur Bedeutung von Innovation
Als Innovation werden neu angebotene Produkte oder Dienstleistungen (Produktinnovationen), die im Zusammenhang mit dem energieeffizienten Holzbau

stehen, sowie technische bzw. organisatorische Neuheiten im Arbeitsablauf von Betrieben und Organisationen (Prozessinnovationen) definiert.

Von besonderem Interesse wären dabei Innovationen, welche die regionale Wertschöpfung bzw. Ressourcen schonendes Bauen wie z.B. die Ausführung von lokalen Betrieben, die ausschließliche Verwendung von heimischem Holz, sowie dezentrale Energiequellen und lokale, ökologische Baumaterialien, betreffen.

Vorgehensweise
Die Befragung erfolgt mittels eines leitfadengestützten Experteninterviews, sowie einer zuvor zusammengestellten Liste von potenziell geeigneten Holzbauprojekten. Die Zusammenstellung der Bauprojekte erfolgte durch Literatur- und Datenbankrecherche, wie den Holzbaupreisen der Bundesländer, der Architekturdatenbank „nextroom“, der klima:aktiv Gebäudedatenbank, dem Staatspreis für Architektur und Nachhaltigkeit und des Forschungs- und Technologieprogramms „Haus der Zukunft“.

Interviewleitfaden
Die Liste der im Vorhinein ausgewählten Holzbauprojekte wird den Interviewpartnern zu Beginn des Interviews vorgelegt bzw. wurde den Experten bereits als Anhang in einem E-Mail zur Verfügung gestellt.

Frage 1: Ich habe eine Vorauswahl von 26 Holzbauprojekten aus zuvor erwähnten Quellen zusammengestellt.

a) Sind Ihnen davon Bauwerke bekannt und können Sie diese den unten angeführten Innovationskategorien zuteilen?

Produktinnovationen	**Prozessinnovationen**
Design	Technologisch
Konstruktion	Organisatorisch
Technische Komponenten	Interaktion
Energieeffizienz	Logistisch
Vorfertigungsgrad	Rechtlich-politisch
	Finanzierungsmodell

b) Welche Bauprojekte sind Ihrer Meinung nach dazu geeignet, eine Fallstudienanalyse, unter Berücksichtigung der vorhin aufgezählten Bedingungen, durchzuführen?

Frage 2: Könne Sie mir andere innovative Projekte empfehlen, welche noch nicht auf der Liste angeführt sind, aber unbedingt näher betrachtet werden sollte.
Schlusskommentar und Verabschiedung

Appendix 4: Experteninterview zu den Fallbeispielen

Allgemeine Angaben

Interviewpartner:

Organisation:

Datum:

Beginn:

Ende:

Dauer:

Titel: Innovation process in the energy efficient timber construction in Austria

Vorstellung und einleitende Erklärung

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Das Institut für Wald-, Umwelt- und Ressourcenpolitik beschäftigt sich politikwissenschaftlich mit den Themenbereichen Wald-, und Holzindustrie. Die Masterarbeit erfolgt im Rahmen des laufenden Projekts „ECO2-Effizientes Bauen mit Holz" gefördert durch die Österreichische Forschungsförderungsgesellschaft (FFG) sowie den Fachverband der Holzindustrie Österreichs unter der Projektleitung von Dipl.-Ing. Dr. Gerhard Weiss.

Die Masterarbeit beschäftigt sich mit Innovationen in der Holzbaubranche und speziell in den Bereichen „Öffentlicher Bau" und „Gewerbebau", errichtet in Österreich im Zeitraum 2006 bis 2012. Der Innovationsprozess soll mittels ausgewählten Fallbeispielen im Detail analysiert und mit Hilfe von Experteninterviews mit beteiligten Akteuren und Organisationen eine Fallstudienanalyse durchgeführt werden. Im Zuge dessen werden das Bauprojekt allgemein, die wesentlichen Akteure, deren Interaktion sowie fördernde und hinderliche Faktoren beschrieben.

Ziel der Befragung

Es soll der Innovationsprozess von energieeffizienten Holzbauprojekten aus den Kategorien „Öffentlicher Bau" und „Gewerbebau", errichtet in Österreich im Zeitraum von 2006-2012 untersucht werden.
Um den Innovationsprozess analysieren zu können, werden hierbei u.a. das Projekt an sich, die maßgeblich beteiligten Akteure, deren Interaktionen sowie förderliche und hinderliche Faktoren bezüglich Entstehung (Idee, Impulse, Vorbereitung) und Ablauf des Projektes (Planung, Produktion, Errichtung, Fertigstellung) näher beleuchtet.

Hinweis zur Bedeutung von Innovation

Als Innovation werden neu angebotene Produkte oder Dienstleistungen (Produktinnovationen), die im Zusammenhang mit dem energieeffizienten Holzbau stehen, sowie technische bzw. organisatorische Neuheiten im Arbeitsablauf von Betrieben und Organisationen (Prozessinnovationen) definiert.

Vorgehensweise

Die Befragung der wichtigsten Akteure erfolgt mittels eines leitfadengestützten Experteninterviews.
Der Leitfaden ist in vier Abschnitte geteilt:

1. Entstehung/ Entwicklung des Projektes (Idee, Impulse, Vorbereitung)
2. Ablauf des Projektes (Planung, Produktion, Errichtung, Fertigstellung)
3. Finanzierung
4. Einführungsphase am Markt und allgemeine Fragen

Der 1. Abschnitt befasst sich mit der Entstehung des Projektes, welche in die Subphasen Idee, Impulse und Vorbereitung unterteilt wurde.

Im 2. Abschnitt soll auf den Ablauf des Projektes eingegangen werden, welcher in die Subphasen Planung, Produktion, Errichtung und Fertigstellung gegliedert wurde.

Die Fragestellung für den 1. und 2. Abschnitt ist identisch.
Es gilt zu beachten, dass in den Abschnitten 1. und 2. die einzelnen Fragen zu den jeweiligen Subphasen beantwortet werden.

Der 3. Abschnitt beschäftigt sich mit der Finanzierung des Projektes, welcher nur für den Bauträger relevant ist.

Die Fragen des 4. Abschnittes beschäftigen sich mit der Einführungsphase am Markt. Des Weiteren werden hier allgemeine Fragen zu zukünftigen Entwicklungen und Herausforderungen des energieeffizienten Holzbaus in Österreich ermittelt.

Interviewleitfaden

Der Interviewleitfaden dient zur inhaltlichen Auseinandersetzung mit dem im Interview anzusprechenden Themenbereich sowie zur aktiven Steuerung und Kontrolle des Gesprächs. Da es sich bei dem qualitativen Interview um eine weitestgehend offene Gesprächstechnik handelt, werden die Unterpunkte nur bei etwaiger Nichtbeantwortung konkret gestellt.

Abschnitt 1: Entstehung/ Entwicklung des Projektes (Idee, Impulse, Vorbereitung)

1. Was war die Ausgangssituation vor Projektstart, wie entstand dieses Projekt? Wie und woher kamen Ideen, Impulse und wie lief die Vorbereitung ab?

    a) Welche Akteure waren am Projekt beteiligt und was war deren Aufgabe (in der jeweiligen Subphase)?

Mögliche Akteure	**Mögliche Aufgabe**
Einzelne Personen	Ideenlieferant
Firmen	Impulsgeber/ Initiator
Institutionen (öffentliche	Informationslieferant

Einrichtungen, F&E Institute)	
Netzwerke /Kooperationspartner	Koordination/ Konfliktmanagement
	(Mit)-finanzierung

b) Was waren die größten Herausforderungen und Probleme und wie wurden die gelöst?

c) Was waren förderliche und was hinderliche Faktoren?

Förderliche Faktoren	**Hinderliche Faktoren**
Monetäre Anreize / Nicht monetäre Anreize	Geringe Eigenmittel /Fremdmittel
Angebot an Information	Hohe Kosten (Investitionskosten)
Förderprogramme/ Initiativen	Rechtlich-politische Rahmenbedingungen (Recht, Normen, Vorschriften)
Kooperation mit Behörden und Kammern	Organisatorische Aspekte (Logistik, Marketing, Öffentlichkeitsarbeit)
Zusammenarbeit mit Dienstleistern, Lieferanten, Kunden,...	

d) Gab es Kooperation auf institutioneller Ebene?

-Verwaltungsorganisationen
-Forschung, Entwicklung, Bildungseinrichtungen
-Interessensvertretungen

e) Wie erfolgte der Informationsaustausch? Was und wer waren die Quellen der Ideen, der Impulse und des Know-hows?

-Forschungs-, und Entwicklungsinstitute
-Firmen entlang der gesamten Wertschöpfungskette
-Öffentliche Einrichtungen
-Netzwerke
-Fachliteratur
-vorhandenes Wissen (Mitarbeiter)

f) Zusammenfassend: Was bzw. wer war wesentlich für den Erfolg in dieser Phase?

Abschnitt 2: Ablauf des Projektes (Planung, Produktion, Errichtung, Fertigstellung)

2. Kommen wir von der Planungsphase zur Durchführung des Projekts:
Können Sie mir schildern, wie das Projekt verwirklicht wurde (in den jeweiligen Subphasen)?

a) Welche Akteure waren am Projekt beteiligt und was war deren Aufgabe?

Mögliche Akteure	**Mögliche Aufgabe**
Einzelne Personen	Ideenlieferant
Firmen	Impulsgeber/ Initiator
Institutionen (öffentliche Einrichtungen, F&E Institute)	Informationslieferant

Netzwerke /Kooperationspartner	Koordination/ Konfliktmanagement
	(Mit)-finanzierung

b) Was waren die größten Herausforderungen und Probleme und wie wurden die gelöst?

c) Was waren die förderlichen und was die hinderlichen Faktoren?

Förderliche Faktoren	**Hinderliche Faktoren**
Monetäre Anreize / Nicht monetäre Anreize	Geringe Eigenmittel /Fremdmittel
Angebot an Information	Hohe Kosten (Investitionskosten)
Förderprogramme/ Initiativen	Rechtlich-politische Rahmenbedingungen (Recht, Normen, Vorschriften)
Kooperation mit Behörden und Kammern	Organisatorische Aspekte (Logistik, Marketing, Öffentlichkeitsarbeit)
Zusammenarbeit mit Dienstleistern, Lieferanten, Kunden	

d) Gab es Kooperation auf institutioneller Ebene?

-Verwaltungsorganisationen
-Forschung, Entwicklung, Bildungseinrichtungen
-Interessensvertretungen

e) Wie erfolgte der Informationsaustausch? Was und wer waren die Quellen der Ideen, der Impulse und des Know-hows?

-Forschungs-, und Entwicklungsinstitute
-Firmen
-Öffentliche Einrichtungen
-Netzwerke
-Fachliteratur
-vorhandenes Wissen (Mitarbeiter)

f) Zusammenfassend: Was bzw. wer war wesentlich für den Erfolg in dieser Phase?

3. Energieeffizienz
a) Wie wurde mit den Themen Energieeffizienz und nachhaltiges Bauen im umfassenden Sinn umgegangen (in den Subphasen)?
b) Wie wurde es gefordert und gefördert?
-Lebenszykluskosten
-Einsatz von ökologischen Materialien

Abschnitt 3: Finanzierung

4. Wie ist das Finanzierungsmodell des Projektes aufgebaut?

-Relevanz der finanziellen Unterstützung
-interne und externe Quellen (private, öffentliche Quellen)
-Förderungen / Förderprogramme

Abschnitt 4: Einführungsphase am Markt und allgemeine Fragen

5. Wie wird das Projekt am Markt aufgenommen und wie waren die Reaktionen bzw. Rückmeldungen etwaiger Betroffener (Projektpartner, Anrainer, Konkurrenz,...)

6. Wie beurteilen Sie das Ergebnis? Wie schätzen Sie die Übertragbarkeit für Projekte dieser Art ein (national/ international)?

7. Gibt es ihrer Meinung nach Bedarf für (gesellschaftliche, politische oder ökonomische) Veränderungen im institutionellen System im energieeffizienten Holzbau.

8. Welche zukünftigen Entwicklung und Herausforderungen sehen Sie für den Holzbau in Österreich?