Master's Thesis
ISRN LUTMDN/TMFL–09/5068–SE

MARKET ANALYSIS OF GLULAM IN EUROPE

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PREFACE

Firstly, I would like to thank Johan Fröbel at the Swedish Glulam Association/Swedish Forest Industry Federation for introducing me to this interesting subject and for letting me do this thesis work.

Secondly, I would like to thank Roland Palm, Jan Söderlind, Bertil Stener and Sarah Segerman at the Swedish Forest Industry Federation for helping me when questions turned up and for contacts for the interviews. Further thanks to Leif Cederlöf at Setra Långshyttan, Roger Roser at Moelven Töreboda and Örjan Kallin, Stig Axelsson and Niklas Ericsson at Martinsons Byggsystem for letting me visit them and to see their production sites. Also thank you to Mikael Eliasson at Setra for the inspiring meeting.

A special thanks to the interviewees in Austria, France, Germany, and in the United Kingdom. Also big thanks to Sven Andersson at Svandata for helping me with the export data. Thank you to Marie Åsell and Alex Stodulka for editing my thesis. Also thanks to Såg i syd for the scholarship.

Last but not least I would like to thank my supervisor at the faculty of Engineering at Lunds University, Fredrik Nilsson at the department of Packaging Logistics.

ABSTRACT

The Glulam producers in Europe are producing more glulam than is used in Europe. The main producers are Austria and Germany with more than 70 % of the total production. On third place is Finland, followed by Italy and Sweden. Interesting to point out is the increase of production from 1999 to 2005 in Austria by 191 %, in Germany by 83 %, in Scandinavia by 143 % and in Italy by 266 %. The largest consuming countries are Germany, followed by Italy and then Scandinavia in 2006. The wooden frame building sector is small compared to steel and concrete. As a comparison, in France, just 15 out of 1 000 construction engineers that graduated a couple of years ago began to work in the wooden frame industry.

From the interviews with people from Austria, France, Germany and the United Kingdom the results was about the same. Knowledge about glulam has to increase, both that the material exists and how to use it. An increase of help to make glulam easier to work with is desired, like software. A prejudice is that glulam is bad to use since it burn more easily and in the countries that does not usually use timber as a frame material, they do not think that wood is strong enough to carry big loads.

There can be an increase of the use of glulam in Europe if knowledge increase since the price of the competing materials rise and the production of glulam is less energy demanding than steel and concrete. The environmentally acceptable arguments are not the first to be pointed out when marketing glulam since the technical aspects are more important.

The results from the environmental comparison in this thesis work showed that glulam is the best material to use when comparing glulam, steel and reinforced concrete.

SAMMANFATTNING

Limträproducenterna i Europa producerar mer limträ än vad som konsumeras här. De största producenterna är Österrike och Tyskland med en sammanlagd produktion på mer än 70 %. Tredje plats innehas av Finland, följt av Italien och Sverige. Från 1999 till 2005 ökade Österrike sin produktion med 191 %, Tyskland med 83 %, Skandinavien med 143 % och Italien med 266 %. Av den volym som produceras i Europa konsumerar Tyskland mest, följt av Italien och sedan Skandinavien. Byggnader med trästomme är dock ett litet segment i jämförelse med stål- och betongsegmenten. En jämförelse från Frankrike visar, att av 1 000 byggnadsingenjörer som examinerades för något år sedan var det endast 15 stycken som jobbade inom träindustrin.

Från intervjuerna som genomfördes med representanter från Österrike, Tyskland, Frankrike och Storbritannien, var resultaten likartade. Kunskap om limträ måste öka, både att limträ finns som ett alternativ och hur det används. Det är viktigt att limträ är lika enkelt att använda som andra material, för detta behövs exempelvis hjälp av mjukvara för att göra beräkningar. Man behöver slå hål på många fördomar, som exempelvis att limträ är sämre vid brand. Man måste också visa att det är ett starkt material i förhållande till sin vikt. Det sistnämnda är viktigt att betona speciellt i länder där byggnader vanligtvis inte har trästomme.

I framtiden är förutsättningarna goda för att användandet av limträ ökar om kunskapen ökar, prisbilden förbättras i och med att konkurrerande material blir dyrare och att limträ är mindre energikrävande att framställa.

Miljöjämförelsen i detta examensarbete visade på att limträ var bäst att använda då det orsakade minsta mängden utsläpp i enheten koldioxidekvivalenter, CO_2-ekv. Stål hade nio gånger så höga värden och armerad betong hade 6 gånger så höga värden.

CONTENT

1 BACKGROUND

Glued laminated timber is called glulam and it is used as construction timber. The technique of producing glulam was further developed in Germany in the end of the 19th century, which increased the possible use of timber. Both size and the knot size were no longer the limiting factors of how much weight wooden beams could carry and how large a building could be. With the glulam beam it was possible to build large-scaled buildings with greater spans than with traditional timber beams. The limiting factor is now transportation, since glulam beams are finger jointed (Gross & Fröbel, 2007). In figure 1.1 it is shown how glulam is produced.

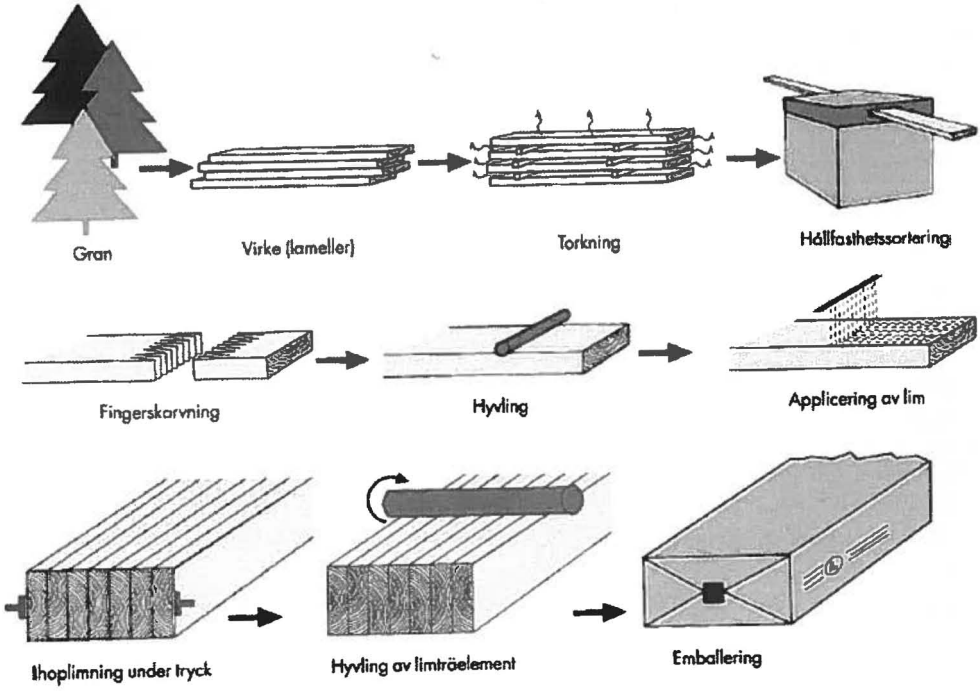

Figure 1.1 How glulam is produced. Spruce is sawn into lamellas that is dried and graded according to its strength. Finger jointing is the next step, then the timber is planed, the glue is added, the lamellas are glued together under high pressure, the glulam beam is then planed and finally it is packed (Gross & Fröbel, 2007).

The competing materials of glulam are mainly reinforced concrete and steel. These materials are much more commonly used.

The Swedish Forest Industry Federation discovered that there was a lack of knowledge about the glulam market in Europe. This also includes the absence of knowledge by European users that glulam is an option when constructing buildings and also the knowledge of how to use it. When glulam is used it is important to know the reason for its usage, if it is chosen for its environmentally acceptable aspects or construction benefits. It is therefore the object of this thesis, to determine the use of glulam in Europe.

1.1 Problem Discussion

The topic for this thesis work was decided to specify the European glulam market since the environmental trend could either be influencing it or not. Glulam is made out of sawn timber which is a renewable building material (Gustavsson & Sathre, 2006). The use of glulam has increased recently in Europe as timber frame constructions gain in popularity (Schuler 2000). The reason can either be that the amount of buildings has increased, or that glulam is taking market shares from steel and/or concrete. There could be variations of the increase in different countries. The European glulam market could also be influenced by the transport distance of the material. If a lot of the glulam beams are usually transported to other parts of the world and it will cost more to transport them, then this amount have to be consumed within Europe instead. For competitive pricing in Europe, it is important to increase the use of glulam here for the glulam producers.

The task of mapping out the glulam market in Europe can be focused on different aspects or different influences. Since there is a difficulty in the beginning to know what will be the interesting parts to focus on, the decision was to have a process steering focus instead of a goal steering focus. This seemed to be the best solution since it was difficult to know what information is available in the chosen area and what the interviewed persons wanted to contribute. The goal for the thesis was then written according to what could actually be reached.

The glulam market is competing with concrete and iron beams. In different markets the rival material is changing but these are the primary competitors. Timber beams can also be a competitor, but for smaller buildings. Timber beams have the disadvantage that the length of a timber beam cannot be larger than a tree can grow and knots and other growth factors influence the strength of the beam. This means that timber beams may look the same but can differ a lot in terms of the weight it can carry. In this thesis work it was decided to focusing on steel and concrete beams when talking about competing materials, since timber beams are not an option (Cederlöf, comm. 2008-02-27).

The largest consumer markets are storerooms, residential houses (municipal and smaller one), barns/cowsheds and other non-residential buildings. Glulam is the most environmental friendly material to use as building material (Gustavsson and Sathre, 2006). The material is not used as much as it could be (Eliasson, comm. 2008-02-25).

It is also important to know why glulam is chosen, if it is only the environmental advantage that leads to the decision to use it or if it is something else. If glulam is considered to be a good substitute to other materials and if the users has the knowledge that glulam is an option, is relevant information. These points will be discussed in this work.

1.2 Aim

The purpose of this thesis is to explore the market of glulam in Europe and to see if the environmental advantage of glulam will have a positive impact.

The aims are:

- To obtain an understanding of how glulam is used today and the forecast for the future.
- The void regarding the lack of data about the glulam production, consumption and export during the latest years in Europe.

- To compare rival materials of glulam with an environmental focus. The rival materials that are focused on in this thesis are concrete and steel beams. The storehouse sector is a good segment to compare the materials.

1.3 Focus and Delimitation

The focus of this thesis is the biggest producing and consuming countries since they are primary users or producers. People interviewed were from Austria, France, Germany and United Kingdom. The construction in Europe is focused on Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Hungary, Ireland, Italy, the Netherlands, Norway, Poland, Portugal, Slovak Republic, Spain, Switzerland, and the United Kingdom. The export of glulam is focused on Austria, Finland, France, Germany, Norway and Sweden since they are most export-oriented (Fröbel, comm. 2008-03-03).

The environmental analysis is chosen in the storehouse segment, since this is the segment that has the most similar look and a simple construction where the comparison between the different materials is more relevant.

Delimitation is the possible increase of glulam use according to changes in distribution and in storage structure. This is not considered in this thesis work. Nor is the information from the customs about import of glulam since not only glulam is shown there.

1.4 Target Audience

This master thesis is written as a Degree Thesis on D-level in Business Administration. It is of interest for students and employees from the universities as well as for people from the industry.

2 METHODOLOGY

The methodology was discussed before the start of the work, and the conclusion was that a qualitative research would be the most appropriate. This is because the result will be based on the knowledge and the thoughts of people with different views. To get more of a general idea of what people think about glulam, qualitative research is the best way of getting most out of it, since it is able to generate valuable data from just a few penetrating cases (Kvale 1997; Shaughnessy 2003; Starrin *et al,* 1991)

The results that were received from the customs had to be controlled by someone who knows which countries that were actually producing glulam since the number used is also including straight-glued joints. When visiting some Swedish glulam producers, the export from Sweden was controlled by them to see if the amount could be accurate.

The selection of who should be interviewed was made in cooperation with Jan Söderlind at Skogsindustrierna (The Swedish Forest Industry Federation). The decision was then to interview some people that had knowledge in some specific areas and also some people that had broader knowledge. Glulam producers from the countries interviewed and people from forest products organisations were chosen. In the United Kingdom there was only one interview with one architect since they are interesting as consumers, not as producers. The approach and the problem discussion may therefore differ within the interview group.

The countries where the interviews have taken place are Germany, Austria, France and United Kingdom. In Germany two persons have been interviewed and three in France. In Austria, three persons were supposed to be interviewed, the reality was five but some of them only answered some part of the questions. The information about Spain and Italy came from two other persons in Austria. From Germany, Austria and France representatives from the glulam industry and the glulam organisations were answering the questions. The interviewee in United Kingdom is an architect that is used to work with environmentally acceptable products. As seen below, some interviewees have been talking about other countries but their own.

The questions were chosen to cover areas that were found to be of interest and also to test theories for market analysis. Since the interviewees have different backgrounds according to the objectives of this thesis, all questions will not be able to be answered by everyone.

2.1 The research design

The work process in this thesis was first to see what information was available and also to find out what information was wanted and how to obtain it. The decision was made that the most efficient way to get the desired information was to interview relevant stakeholders that would hold different views of the glulam market. The reason for choosing different view is that hopefully this will give a more accurate answer to the questions, since people with the same starting point often see the same thing in the same way. This was wanted to be avoided, plus the study to remain unbiased. When deciding who to interview together with Jan Söderlind, it was considered to be most efficient to interview one or two representatives from a specific background from the countries. A qualitative design of this thesis work was considered to be more efficient. The qualitative analysis is focusing on the whole phenomena rather than focusing on specific words (Olsson & Sörensen, 2001). Qualitative methods are often used when the aim primarily is to gain understanding (Holme & Solvang, 1997). A disadvantage with a qualitative research is after all that every unit that is studied needs a lot of

recourses, which means that the researcher only can focus on a few number of units (Holme & Solvang, 1997).The advantages of choosing the method was considered to give more value to the analysis than choosing the quantitative method.

2.2 Data Collection

The theories that were chosen in this work for the interviews were the PESTEL-analysis and also the SWOT-analysis. From these theories and other questions that were considered to be of great importance, the questionnaire was made. Some questions were not answered by the interviewees. The reason for this was either that they did not know the answers or they did not want to answer. Since production volume can be considered to be business secrets, this information was collected from another source. The data collected can be divided into primary, secondary and tertiary sources. Primary sources are the empirical information in the thesis, the raw material that is collected in the survey (Bell, 2000). The secondary material interprets the raw material. It also constitutes the theoretical framework. Tertiary sources are sources like textbooks. The primary sources in this thesis are the results from the interviews. The secondary are the literature and the toll numbers from the customs. The tertiary sources are not used very much in this work, only for some descriptions of some not well-known expressions.

Some data was collected from the toll numbers. This is used to visualise the flow of glulam in Europe. The toll numbers also includes other things than glulam, therefore the numbers are not exactly right (Svandata, 2008). The countries chosen to look at the export numbers from Svandata are countries where it is known that they export glulam (Fröbel, comm. 2008-03-03). Some information is also collected from trade magazines.

2.3 Questions

The questionnaire is the method of obtaining the answers for the questions that is important and hopefully to see the different or the same view of the topics. As mentioned in chapter 2.2; some of the questions have not been able to be answered by all interviewees since they are from different types of companies or organisations, or they did not want to answer. The questionnaire was the following:

2.3.1 Questionnaire about glulam

The questionnaire focuses on five different areas; the potential of using glulam, the actual use, the forecast, the market today and the comparison between glulam and rival materials. Within these areas, the respond to the questions are supposed to give an overview of the specific areas and also to point out if the answers differs between the interviewees or between the countries. The five different areas were;

2.3.1.1 The potential

The results of the questions in this part were to determine where glulam is used today, how much that is used and how the response was towards this material from the one working with it. What did they think about the advantages and disadvantages of using glulam. What was their opinion about the situation today for glulam and what did they think about the future. Some of these questions were slightly close to the same later on in the questionnaire; the

reason for this was to see if the response is the same or if it differed when it was asked in a different way. The analysis should give the result of which potential glulam has.

2.3.1.2 Use of glulam

This group of questions provides information of how much glulam was used today and how much they were producing. An overview of the situation and market today was also included in this part.

2.3.1.3 The forecast

This part tried to give an answer to what the interviewees thought about the future. This included which markets are considered to be important, the largest producing countries and how big the different segments will be in the future. The important question if the environmental aspects would influence the use of glulam in the future was a part of this.

2.3.1.4 The glulam market

This part was giving the answer of the questions based on the theories used in this market analysis. The reason for this was to provide a general view to define the market. This is according to the SWOT- and PESTEL-analysis that will be described in chapter 3.1. Here it was determined what influence the market in the different countries.

2.3.1.5 Comparison:

The questions were comparing glulam with competitive materials. Here we can see the rival materials and their advantages. In this part the questions discussed what would influence the use, the durability and the perception and who decides which material to use. The interviewees were asked if they thought that the use of glulam will increase.

3 FRAME OF REFERENCE

The frame of reference includes all that can explain the surroundings of the glulam market. This includes literature that discusses the market and different aspects that influence the glulam market within itself and toward others. More information of glulam and just a little information about the market in Europe today are also in this chapter. Information of construction in Europe in recent years and forecasts until 2010 is important for analysing the potential demand and export of glulam from the largest glulam producing countries in Europe influence the market too. The following parts in this chapter will show this.

3.1 Literature

The purpose for the choice of the literature was divided into 4 parts. The first part was to get the main questions for a market analysis. For this purpose the SWOT and the PESTEL-analysis were chosen. Especially the SWOT- analysis is very well known. Therefore the interviewees will recognise the questions and will probably feel comfortable and are accustomed to these terms. This hopefully makes the response to the questions more reliable. The PESTEL-analysis may not be quite as well-known, but since it is a quite simple analysis too, it is easy to answer following a brief explanation.

The next three parts are the analysis literature. The search has been made according to the environmental aspects for the glulam market, the importance of knowledge and also the vision of the competitors, is it mainly in the market or between different markets, in this case within the glulam market or between glulam and competing materials.

3.1.1 The analysis

3.1.1.1 The SWOT-analysis

SWOT is an acronym for strengths, weakness, opportunities and threats to a companies market, its niche or the whole market. (Kotler & Armstrong, 2008). This is a common and easy way to get to understand the market that is examined. The advantage of using this theory is that a lot of people know it although they have not so much economic knowledge and it determines the specific characteristics of the market. The people in the organisation then have the possibility to adapt to its indentified surrounding.

3.1.1.2 The PESTEL-analysis

PESTEL is an acronym for the words Political, Economic, Social, Technical, Environment and Legislative. (Johnson & Scholes, 2002). The element in the surroundings that are or may influence the organisation is analysed. It provides a useful framework for analysing the environmental pressures on a team or an organisation. The political part is analysing the regulations and the political decisions that are influencing the market. The economic trends are if there are some global trends at the moment, if there are some trends more locally and if there are some industry trends. The social trends can be cultural changes, some expected changes, demographic and family trends. The technological trend includes inventions, new discoveries, research, energy use, health, manufacturing advances, information technology transportation, recycling and so on. The environmental trends are cost implications, public

opinion, sites and location. The legislative trends are for example the European legislation and the more regional ones

3.1.2 Competitor-oriented Objectives

One other theory that is chosen to analyse in this thesis is the Competitor-oriented Objectives: The Myth of Market Share by J. Scott Armstrong and Kesten C. Green that was published in the International Journal of Business in 2006. The finding indicates that a competitor-oriented objective reduces profitability. The competitor-oriented objectives such as market-share targets are commonly used by firms and are promoted by academics. This has been ignored by managers although there is evidence that the profitability reduces when this has been used, (Armstrong & Green, 2006).

General wants for managers is to beat their competitors. What the authors want to emphasise is the relationship between competitor-orientation and performance. It was commonly used to see how well the company was doing by comparing its market shares with other companies in the same industry, especially in large firms. It was believed that business was like warfare and that the winner's proof in the industry was the firm with the greatest market share. What was explained in this document is that a company should be result-oriented, not competitor-oriented. Armstrong and Green (2006) compared some investigations that had compared companies that were profit or result-oriented. The finding was that the companies that were competitor-oriented were less profitable and had more often gone bankrupt than the profit oriented-companies. The authors recommend that in education, competitor-oriented objectives should not be advocated in classes or textbooks. In some textbooks they are clarifying the confusion between market share and profitability (Dranove & Shanley, 2006). They are saying that a strategy designed for increasing the market share and thereby increasing a firm's profitability does not exist. There is no such mechanism. A lot of the business school professors do not adopt this, instead they teach the students to develop techniques to gain market share (Armstrong & Green, 2006).

Armstrong and Green (2006) also recommend developing profit-oriented decision aids. After studying investigations about correlation with Boston Consulting Group matrix[1] and profit, it was found out that some decision aids for managers are based on competitor-oriented objectives. One example is the portfolio planning method where the performance is relative to the competitors. It was then found out that when the Boston Consulting Group matrix was used as a decision aid, it reduced the profitability of subject's decisions (Armstrong, Brodie, 1994). The companies using the Boston matrix also had lower return to shareholders (Slater, Zwirlein, 1992). It was also found out that the firms had a lower return on capital than the one not using them (Capon *et al*, 1987). One other example of the competitor-oriented technique is the experience curve strategy. It requires that the firm cut prices to build volume in order to cut down its cost curve. The idea is that the company should cut down its prices faster than the competitors'. This behaviour often leads to a more intensive competition and it reduces profits, especially in the long run (Lieberman, 1987). Companies and business schools still promote these ideas, so Armstrong and Green (2006) are proposing to disseminate findings through actual knowledge. Not just to say what you have been taught, but also to listen to it

[1] The Boston Consulting Group matrix is based on the product's life cycle and has divided the products into Cash Cows, Stars, Question Marks and Dogs. The Cash Cows have low growth but high market share, the Stars has high growth and high market share, the Question Marks has high growth but low market share and the Dogs has low market share and low growth. The idea for this matrix is that the bigger the market share or the faster the growth, the better the product is for the company (Stern, 1998).

critically and to see if the relationship you have heard about is there and if it is because of the reason you have been learned. One example of this is in Kotler's Marketing Management that included the Boston Consulting Group matrix in 1980, but after critique from several authors they have removed it in the 2006 edition (Armstrong & Green, 2006).

However, it has been shown that market share is positively correlated to profits. According to Armstrong and Green (2006) this is because firms with better offerings tend to achieve higher market shares. The higher market share is a cause, not the reason for the strategy.

3.1.3 Knowledge

Another prospect in the glulam area is the knowledge issue. Since not all countries in Europe have traditionally built with wood, there can be a lack of knowledge about how wood based products should be used. A research article that is discussing this is Guadamillas *et al* (2008). There it is concluded that knowledge management is a key factor for corporate entrepreneurship and growth success. Therefore it could be understood that corporate entrepreneurship involves the internal development of new products and services of a firm or the enhancement and extension of existing products of services. It is also understood through the exploitation of new business lines (Sharma & Chrisman, 1999). The result of the entrepreneurial activities in terms of new knowledge when combined with the existing knowledge is increasing the existing products of services (Galunic & Rodan, 1998). The firm may also seek to develop and acquire resources when such resources are necessary for growth and organisation (Itami & Numagami, 1992). The study is based on the fact that the management of the process through which the knowledge is created and applied is the organisational competitive tool which managers should recognise and develop a basis for establishing their strategy in order to achieve competitive advantages (Guadamillas *et al,* 2008).

The process of the firm growth can be explained using the Resource-based view which means the differences in performance among firms and the basis of competitive advantage which can be explained by the resources and capabilities that the individual firms possess (Barney, 1991; Hoskisson *et al*, 1999). The view analyses the existence of interactions between strategy and resources. It also explains the resources that the company possesses or control as the result of the firm's development and growth process (Teece, 1997). Each firm must develop and implement its strategy considering its specific circumstances. The conversion of technical ideas into new businesses and new services is based on the understanding of the synergies and interactions between the different knowledge possessed by the firm, their technologies and their internal organisation (Guadamillas *et al,* 2008).

3.1.4 Environmental focus vs. profit

This thesis also has an environmental focus since glulam provides a good alternative for the environment when choosing between different building materials. One article that discusses this is Hayam Wahba in "Does the Market Value Corporate Environmental Responsibility? An Empirical Examination" (2008). This article was also analysing the question in the Egyptian context. The author says it is because the literature is dominated by the Anglo-American inventory. The Egyptian perspective is not included in the focus of the analysis in this thesis.

In the text Wahba (2008) are both discussing Porter and Van der Linde (1995) that comment that strict legislation can lead to improvement in corporate environmental attitude and practice

by inducing a firm's innovation that it even can go beyond the requirements. Palmer *et al* (1995) argued against it and clarified that usually the profit is not sacrificed by the business organisation for the sake of environmental protection. The relationship between profitability and environmental responsibility has been positive according to some documents (for example Schnietz & Epstein, 2005; Waddock & Graves, 1997). In other documents the relationship has been negative (Wagner *et al,* 2002; Jaggi & Freedman, 1992) and in others no significant relationship has been seen (Murray *et al,* 2006; McWilliams & Siegel, 2000).

Wahba (2008) is introducing the stakeholder theory in his article, that every corporate has its unique stakeholders that influence its actions, and also are affected by it. The corporation also has predetermined internal and external contracts with different parties which need to be fulfilled (Wood, 1991). The stakeholder theory assumes that any development in the corporate's environmental practise will be positively reflected on its profit. This is because of the inverse relationship that exists between the explicit and the implicit costs of the firm. If a firm or an organisation decides to act in an environmentally irresponsible way by reducing cost of pollution prevention and protection to bring down its implicit costs, it will experience higher explicit costs. This is because the competitive edge will be exhausted (Waddock & Graves, 1997).

The conclusion that Wahba (2008) had, is that there is a positive correlation and that it pays to be environmentally acceptable. It is also said that the stakeholder theory provides support evidence from the conclusion in the paper.

Hoffman (2002) is discussing climate change in terms of Business strategy. Here it is said that climate change is an issue of capital asset management. Companies that are investing a lot of money in their production sites do not want the factory to be obsolete before its time. This means that the company does not want to invest in a plant that will not be used in only a few years to its maximum capacity.

It is also discussed that climate change is a matter of market competences. This means that if there are opportunities to increase profit by development of energy efficient processes of low emission vehicles then it will be taken. What can differ between different companies is the core competence and the opportunities for using climate change controls to their own advantage. The strategies can be cost reduction and profit improvement in six areas. They are operational efficiency, risk management, capital acquisition, market demand, strategic direction and human resource management. Given the specific knowledge a company has, it can be used for lowering energy costs, lower insurance premiums, increase the market share by appealing to the costumers and so on.

Thirdly is that climate change is an issue of global competitiveness (Hoffman, 2002). Here it is important that both the developed and the developing countries are competing on the same level, so it is not just the developed world that will pay extra for reducing their emission of greenhouse gases. This gives the developing countries a short-cut towards the more efficient and better production method for the environment; it promotes technology transfer to the developing world.

Finally climate change is also an issue of managing institutional change (Hoffman, 2002). The companies that will decrease the emission of greenhouse gas will have a direct impact on the price of energy. The problem for the industry groups is that they lack credibility. The advantage for the companies that have a difficulty of communicating its environmental focus is that they get rewarded by cutting their costs.

3.2 Glulam and its production

Of great importance for the understanding of glulam is the knowledge of what glulam is and how it is produced. Glulam is mostly made of spruce lamellas that are glued together under high pressure. The gluing part of the production can either be using hot press glue technique or heatronic gluing. When using the first mentioned technique, most of the energy used generates from the planing of the lamellae. The heatronic gluing is more energy demanding and is a more modern technique where the advantage is in the production technique (Erlandsson, 2007). There has to be at least four lamellae to be called glulam. It is used as construction beams and can carry a lot of weight compared to its own weight. The lamellae effect is the advantage of gluing pieces together, and it is so because of the strength loss that is influencing a wooden beam when a force is pointed toward a knot. The probability that this attenuation due to the knot will be at the same place in the lamellas is very small, so the glulam is stronger due to the different wooden elements that are glued together (Gross & Fröbel, 2007).

The lifetime of a reference beam is more than 50 years or unlimited if it is built-in and above the ground in a dry atmosphere. Normally, there is no maintenance work on glulam if it is built-in. If the beam is outside, it should be treated like normal timber (Erlandsson, 2007).

The length of the beams is increasing compared to the one made from timber, since it is finger jointed. The glue used for the finger jointing and the gluing of the lamellas are very strong, it must be stronger than the wood itself (Cederlöf comm. 2008-02-27). The requirement on the glue is this high because this technique is the most important thing the glulam industry is based on (Roser comm. 2008-03-28).

The use of glulam in the long run is influenced by the sawmill industry that is influenced by the forest growth. In Europe the annual wood harvest in the 1990s were 60 % of the net growth (UNECE/FAO 2000). If this continues, the age class of the forests will increase which leads to a decrease of the growth in a longer run, since older forest grow slower (Nabuurs *et al*, 2002). If the harvesting levels would increase, then the age structure of the forests in Europe would be younger and the growth would increase (Sathre, 2008).

3.2.1 The environmentally acceptable product

Over 99 % of the glulam beam is wood. Through the photosynthesis, the tree are using carbon dioxide (CO_2) and sunlight, and are breaking the molecules apart into carbon and oxygen and then storing the carbon and releasing the oxygen (O_2). The tree contains a lot of carbon, 50 % of the dry weight of wood is carbon (Sathre, 2008). This carbon will be released to the atmosphere again when the wood is decomposed or burned, but until then, the tree will store the carbon. Since the people of the world today are increasing the use of fossil fuel, the CO_2-content in the atmosphere is constantly increasing. The reason why this increase of CO_2 is unwanted is that it is the most common greenhouse gas (GHG). The effect of the greenhouse gases are that the greenhouse effect in the world is increasing. The greenhouse effect is not a bad thing when the earth is in equilibrium, then the result is just that the average temperature on the earth is 15°C and not -18 °C (SMHI, www). The antropogenic influence on the climate should more accurately be called global warming. It means that the greenhouse gases increase, especially CO_2. This influences the temperature since the greenhouse gases are isolating the earth from the long waved radiation that comes from the earth. This heat will then be reflected towards the earth again opposed to leaving the atmosphere. The radiations from the sun have a short wave length and high energy. The radiation that is not reflected by

the ozone layer and goes into the earth, will then be absorbed and go out again with long wave length and less energy. This out-going part is the one that will reflect back to the earth again when there are more of the greenhouse gases (SMHI, www). The effect of a warmer climate is much talked about these days with the melting ice at the poles, the risk of increase of diseases for humans, animals and plants and increase of dry land and so on. Because of these effects, it is good if the amount of CO_2 in the atmosphere will decrease or at least not increase at the same speed as it has been. The uses of fossil CO_2 are reduced since glulam are replacing poles and beams that are demanding fossil CO_2 for its production. When a glulam building is demolished, often the beams are reused or burned, which also reduces the use of fossil CO_2 (Kallin comm. 2008-02-28).

3.3 The market of glulam

In 1999 Germany's demand of glulam was 55 % of Europe's demand, as shown in Figure 3.3.1.

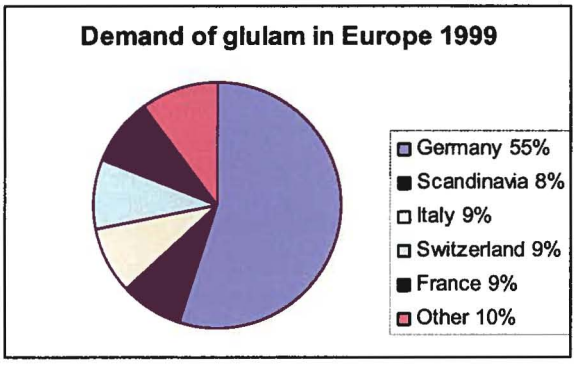

Figure 3.3.1 The demand of glulam in Europe in 1999 (Schuler, 2000).

The glulam beam manufacturers in Central Europe have decreased their production to two shifts in stead of three shifts in the beginning of 2008. The demand at a European level is likely to be more or less like the last year, 2008 is going to be a largely balanced year. (EUWID, 18/2/08)

In Germany, the housing is predominantly masonry (stone based) but wooden houses are increasing because it is more energy efficient and the government is requiring higher energy efficiency for multi-unit homes. Also that the construction period is 3-4 months for wooden houses compared to 9-12 months for masonry buildings makes people prefer the wooden houses although they are not necessarily cheaper. One third of the wooden prefab houses sold are sold as partly finished projects requiring much labour input. (USDA Foreign Agricultural Service, GAIN Report 12/15/2005)

The USDA Foreign Agricultural Service, GAIN report in 2005 says that the main suppliers of softwood lumber to Germany are Russia, Sweden, Finland and Austria. It says that a large amount from the lumber exported from Scandinavia is re-exported as construction lumber to the United States. The amount of exported glulam to the United States from Germany is small. The maximum amount exported is less than 3 % of the totally exported amount.

In Finland, Stora Enso wants to start a glulam production site in Kemijärvi when they are closing the production they have there now (timber-online, www). This can be interpreted as optimism for the glulam market.

The use of timber in houses differs between countries and areas. In Europe only 10 % of the houses are timber frame constructions and 90 % are concrete/steel based. In North America 90 % of the houses are timber frame constructions. In Japan the amount is 50-50, but 86% of the imported glulam are used by the building sector. 75% of Europe's production will continue to be exported to markets such as Japan. (ECE/FAO Forest Products Annual Market Review, 1999-2000).

In 2000, the outlook for engineered wood products (EWP) was believed to be excellent thanks to the need for efficient construction techniques, growing environmental concerns, and the universal requirement for affordable shelter (ECE/FAO Forest Products Annual Market Review, 1999-2000). If this is the case, the question is if this knowledge do lead to an increase of market share in the beam market? If the competitors are steel and concrete, not other wood composites and lumber, is the forecast true the years ahead? In the writing from ECE/FAO they are saying that EWP will capture market share from maturing conventional building material, there the market share of the non wood composites is considered to develop. The fact that EWP can be made from young, small diameter trees, is considered to enhance the wood market since it is providing a market for lower quality fibre. This makes EWP compete with steel and concrete in the large non-residential building construction market. Jaakko Pöyry is in 2000 forecasting a growth in the European glulam production from about 900 000 m^3 in 1990 to 1 300 000 m^3 1999 to 1 800 000 m^3 2002-2003 (ECE/FAO Forest Products Annual Market Review, 1999-2000).

Worldwide the consumption trends are varying. In Scandinavia and North America glulam is used for residential constructions, in Europe it is used for commercial and non-residential markets and in Japan glulam is used both for residential and commercial end uses (ECE/FAO Forest Products Annual Market Review, 1999-2000).

The advantages of EWP are the technical properties and the conversion efficiencies. The technical properties are the uniform strength and the enhance design values since it both saves labour and production of material. Conversion efficiencies that the production yields from a tree are significantly higher than lumber recoveries. The valuable forest resource is extended. EWP are the future of wood building materials since it ensures that the forest products are cost competitive on an installed cost basis when compared to all alternative building materials (ECE/FAO Forest Products Annual Market Review, 1999-2000).

Germany is a country of abundant forest, as an industry study about the German forest and wood-working industries concluded in 2005. The industry was then employing more than 1.3 million people, which is more than the German automobile industry. A number of companies have been investing in new processing facilities from 1995 onwords. In earlier days, the German forest owners saw their forest as a saving account, especially the small private forest owners. The consequence was that the forest was under-harvested. Other facts that influenced a higher harvest rate was that the saw milling industry became more consolidated and the

increase of using wood as an energy resource. Germany's export has been stimulated by the drop of the Euro the latest year before 2005. The Euro compared to the U.S. Dollar has decreased with 23 % from 2002 until October 2005 (Achilles, 2005).

In Germany the total inventory of wood is 3.38 Billion cubic meters (CUM) followed by Sweden with 2.93 Billion CUM and France with 2.89 Billion CUM. The re-growth in Germany is calculated at an average of 55 CUM/hectare.

3.4 Construction in Europe

In the 64th Euroconstruct Conference in Vienna November 2007, the European Construction Market Trends to 2010 were shown (Czerny & Weingärtler, 2007). Here the trends are easy to compare, since the amount of building starting in different countries is estimated in the same unit. For Austria, the trends are shown in Figure 3.4.1 just below:

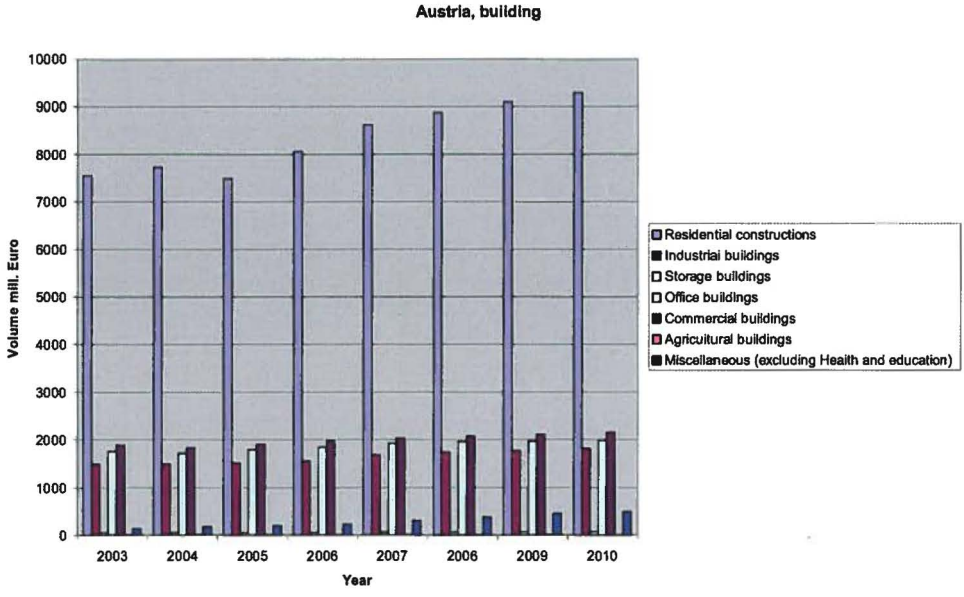

Figure 3.4.1 Building in Austria in volume million Euro (Czerny and Weingärtler, 2007).

In figure 3.4.1 it is shown that residential constructions have the largest volume of all groups. In Austria, the residential construction has increased during the latest years, and is estimated to do so the coming years. Industrial buildings are also estimated to increase, as are office buildings, commercial buildings and miscellaneous (where health and education buildings are not included). The segment of agricultural and storage buildings are not large compared to the other groups and are not estimated to increase. The population in Austria is estimated to increase by 1.2 % to 2010.

For the following countries see the figures in Appendix 2. Construction in some European countries. The changes in the different countries are mentioned. For more details, see Appendix 2.

For Belgium residential constructions is expected to rise to 7000 volume million Euro in 2010 and industrial buildings will increase by about 80 % when comparing year 2003 and 2010. Office buildings will increase by about 18 % from 2003 to 2010. Commercial buildings are estimated to be about the same in 2010 as it has been from 2006, so no increase. Agricultural buildings had its maximum building volume in 2007 with 50 million and are slightly decreasing.

In Czech Republic, residential buildings are estimated to increase by 94 % from 2003 to 2010. All other groups are increasing too, but not as much.

Denmark's residential buildings increased from 2003 to 2006 and are estimated to decrease by approximately 22 % from 2006 to 2010. The other groups will increase except agricultural buildings that will be about the same as it has been during previous years.

In Finland residential houses are estimated to decrease slightly each year from 2007. The same trend can be seen in the other groups too. Interesting to add is that the population in Finland is estimated to increase more than in the previously mentioned countries.

France's residential houses are estimated to decrease slightly each year from 2006. In France the gap between residential houses and the other groups are wider than for the earlier mentioned countries. Office buildings are the group that is forecasted to increase by about 50 % compared with 2003, the other groups are about the same each year. There is also a figure showing the building area of housing starts in France (Figure A2.7). Here it is shown that in 2006 agricultural buildings and storage buildings (non-agricultural) were about the same. Storage buildings have increased its share from 1995. Compared to 1995, office and commerce buildings have increased totally, but have had bigger shares of the segments before 2006.

In Germany the residential constructions have decreased compared to 2003, but the forecast is that it will increase from 2008. The other groups are about the same. In Germany the population is estimated to decrease from 82.3 million to 82.2 million in 2010. The number of housing starts has been decreasing from 1995 to 2006 (where the figures for 2006 were forecasted). This is shown in Figure A2.9.

In Hungary, the residential construction has been decreasing for the latest years but is estimated to increase by about 15 % to 2010 and will then be of almost the same level as in 2003. The groups except agricultural and miscellaneous buildings are increasing. Agricultural and miscellaneous buildings are slightly decreasing.

Ireland's residential buildings were increasing from 2003 to 2006 and then decreased until 2008. The estimation is an increase to almost the same level as in 2003. The other groups are more or less increasing during the period.

In Italy residential buildings are estimated to decrease from 2006 by about 5 % each year. The other groups are slightly increasing or at the same level in this forecast. The population is estimated to increase from 59.4 now to 59.8 million in 2010.

The Netherlands's residential buildings are estimated to increase the following years, but not as much as it has been during the last years. Office buildings are also estimated to increase, the other groups are about the same.

In Norway the residential houses have been increasing rapidly from 2003 to 2007, but the increase is estimated to slow down to just a small increase until 2010. The other groups are estimated to be about the same from now until 2010.

Poland's residential buildings have been increasing yearly from 2003 and are estimated to do so until 2010. The yearly increase is estimated to be about 9 %. All other groups are also estimated to increase. In Poland the population is estimated to decrease slightly.

In Portugal the residential constructions have been decreasing and are estimated to be at about the same level from 2008 until 2010. Commercial buildings are estimated to increase some in the future and also office buildings.

In the Slovak Republic residential buildings have increased by about 20 % every year from 2003 until 2007. Now the increase is estimated to slow down to just a small increase every year until 2010. Industrial buildings were increasing until 2006 but are estimated to decrease until 2010. The rest of the groups are estimated to be about the same as it has been during the latest years.

In Spain residential buildings increased from 2003 until 2006 but will decrease by about 7 % every year until 2010. Industrial buildings will increase slightly and the other groups will be about the same as today. Number of housing starts is shown in figure A2.19 and there it is shown that residential houses did increase until 2006. The population was 45.2 million in 2007 and is estimated to 46.6 million in 2010.

Sweden's residential buildings have increased during the latest years and are estimated to be about the same the following years. The forecast for the other groups are slightly decreasing or about the same as today.

Switzerland's residential buildings have been decreasing since 2005 and are estimated to do so until 2010. The other groups are about the same as they are today and have been the latest years.

United Kingdom's residential constructions are increasing during the following years according to the forecast and have been increasing more rapidly from 2003 until 2007 than it will be in the future. Offices and commercial buildings are increasing during the following years, but offices will stop growing in 2010.

When distinguishing between wooden frame buildings and concrete or steel framed structures, it is important to know that in a timber frame building wood is often not the only sole material used and a concrete building has also wood in it. Often in a wooden house the foundation is in concrete. In a house built in reinforced concrete, wood is used in roof-framing, doors and windows etc. Also wooden-framed buildings may need a lot of plasterboard to cover the wooden framing (Sathre, 2008).

3.5 Export of glulam

The following information about export is from Svandata and the toll number for glulam includes other types of glued wooden lamellas. In the bellow text it is shown what is included in the toll number: "4418901000 JOINERY AND CARPENTRY, OF GLUE-LAMINATED TIMBER (EXCL. WINDOWS AND FRENCHWINDOWS AND THEIR FRAMES AND COVERINGS, DOORS AND THEIR FRAMES, COVERINGS AND THRESHOLDS, WOODEN SHUTTERING FOR CONCRETE WORK, SHINGLES, SHAKES AND PREFABRICATED BUILD". For this reason, the numbers are not totally reliable.

The majority of Austria's export of glulam goes to Italy and for the latest years Japan is number two before Germany that now is third.

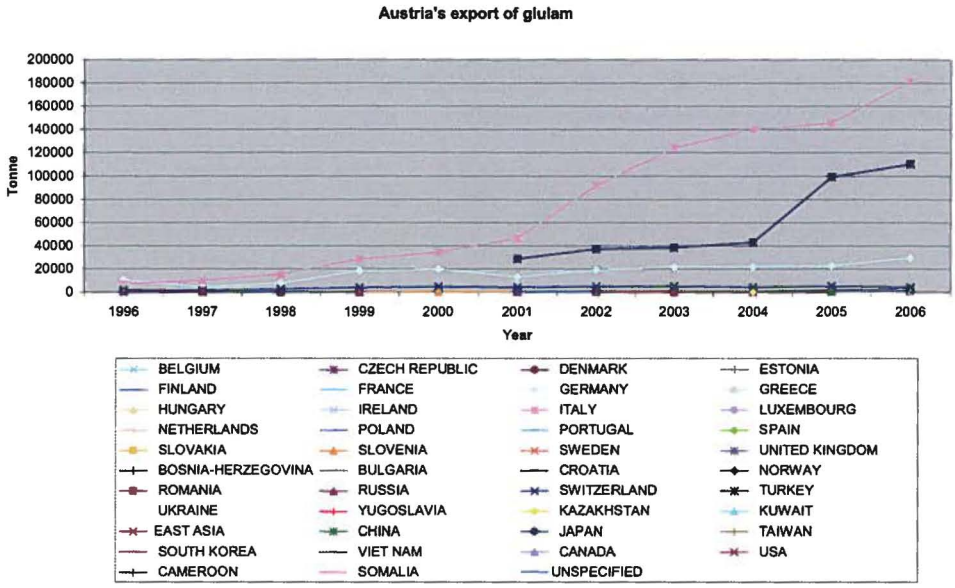

Figure 3.5.1 Export of glulam from Austria (Svandata, 2008).

The figures for the export of glulam from the following countries are shown in Appendix 3. Export of glulam. The source for the export is the same as in Figure 3.5.1, Svandata (2008).

Finland is mainly exporting glulam to Japan, but also to Italy, Norway, France and United Kingdom.

France is mainly exporting glulam to Spain, Belgium, Germany, Portugal, Ireland and to Switzerland.

Germany's export to Italy has increased much during the latest years. The export to Austria is fluctuating some, and have gone from the first and second largest export market to the fourth. Now Switzerland and France is number two and three. Spain, Japan and USA are the following export markets for Germany.

The export of glulam from Norway has decreased much from 2001 until 2007. In 2001 most of the export went to Japan, but this was ended in 2003. The exports to Germany and Switzerland have also decreased from the second largest and the third largest export countries. According to the figures from Svandata (2008), Switzerland was the country that Norway exported most glulam to, and Faeroe Islands were the second one followed by Poland.

The export of glulam in Sweden has been dominated by Japan, with a wide gap to the second country that most of the time has been Germany and Norway on the third place. United Kingdom and Italy are the following countries.

4 RESULTS

In this chapter the result from the interview are displayed as well as the results from the information search of European glulam production.

4.1 PRODUCTION

The production of glulam in Europe has increased rapidly in some regions during the latest years. The most important regions are Austria, Germany, Scandinavia and Italy according to Der europäischer Markt für Brettschichtholz (2006). For that report, numbers from EUWID[2] have been used. The increase in these regions is shown in Table 4.1.1. Interesting to point out is that the largest increase is in Italy, followed by Austria and then Scandinavia. Germany's increase by 83 % only took them to the fourth place. When comparing the numbers in Table 4.1.1 with figure 4.1.2, it is shown that Germany's increase is from a larger level than the others. Austria has been on second place almost all the time. Finland is now the third largest glulam producer in Europe and Italy is the fourth followed by Sweden.

Table 4.1.1 Difference in volume produced glulam from 1999 to 2005 in the most important regions in Europe.

	1999 (million m^3)	2005 (million m^3)	Difference in %
Austria	0.43	1.25	+191 %
Germany	0.64	1.17	+83 %
Scandinavia	0.28	0.68	+143 %
Italy	0.06	0.22	+266 %

In Europe, glulam production has increased from about 900 000 m^3 in 1996 to more than 4 000 000 m^3 in 2007. This change is shown in Figure 4.1.1. To compare the numbers, the increase is 444% in about ten year time.

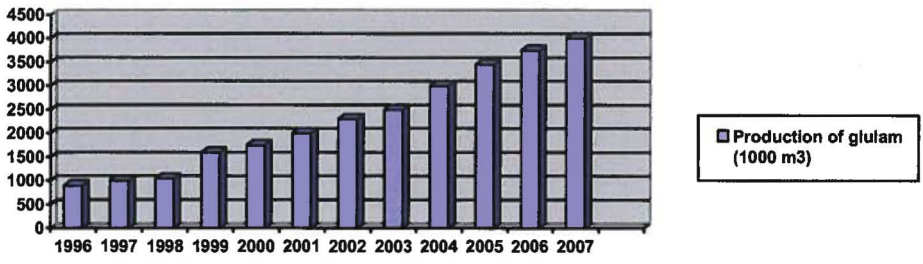

Figure 4.1.1 Total production of glulam in Europe during the last 10 years (source EUWID, 2006).

[2] The reply to the survey EUWID was about 53 %. The volume this group has is more than 70 %. The one not responding to this survey has been estimated from other sources (EUWID, 2006).

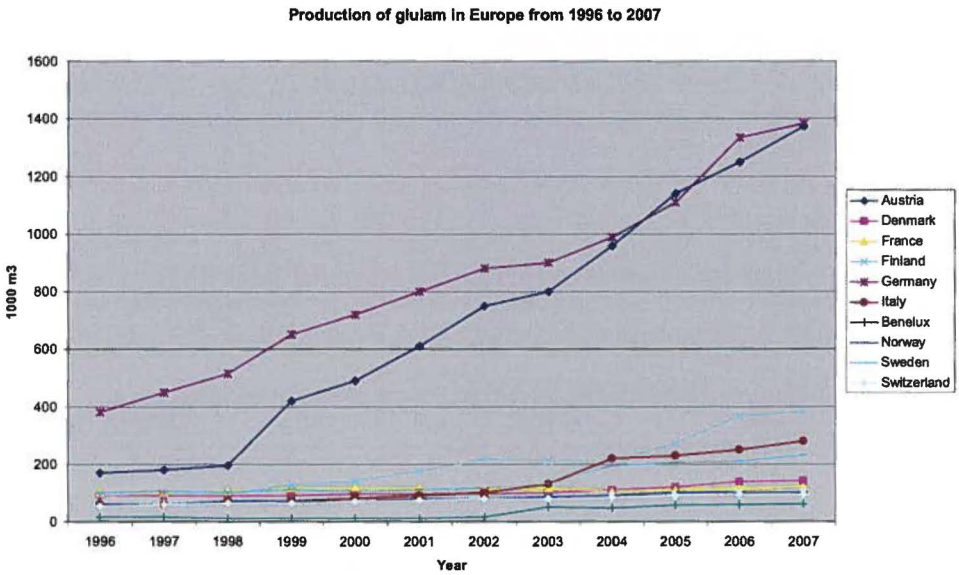

Figure 4.1.2 The production of glulam in Europe and compared between different countries (source EUWID, 2006).

The changes in the market volume of recipient countries according to the estimations made by EUWID (2006) are shown in Figure 4.1.3. Here it can be seen that Germany is the largest recipient market in 2006 and was so also in 1999. Second was Italy in 2006, in 1999 Japan had that place. Scandinavia and other countries are the recipient markets at about the same level in 2006.

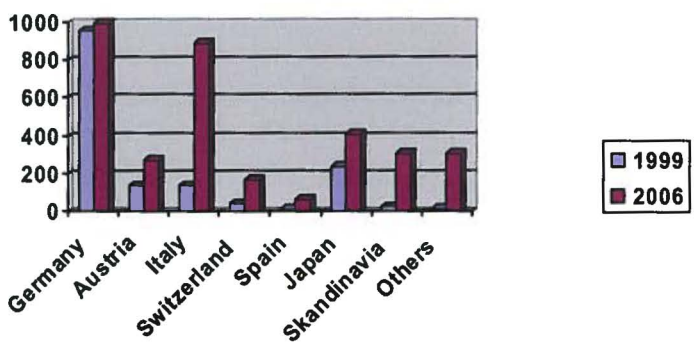

Figure 4.1.3 The difference in Market Volume for recipient countries in 1000 m^3 (EUWID, 2006).

4.2 RESULTS FROM THE INTERVIEW

Here are the results from the interview presented. Each chapter will start with a conclusion of the different countries. To get more information from the interviews, the chapter about each country should be read.

4.2.1 Potential

In this chapter the interviewees answered questions about market share of glulam in their country, the advantages and disadvantages about glulam. Also the situation today and what they believe is the future for glulam. A summary of the answers is in Table 4.2.1.

Table 4.2.1 Comparison of answers from interviews according to potential.

	Austria	**France**	**Germany**	**United Kingdom**
Market share	• 10 %	• 5 %	• 14 % (wood constructions)	• 2 %
Advantages	• Fire resistance • Weight • Ecological arguments	• Fire resistance • Long span • Well-known by major companies	• Less time to build • Cheaper price • Available material • Positive feeling	• Environmentally friendly architecture • Steel price rising
Disadvantages	• Lack of education	• Lack of knowledge • Traditional concrete country	• Fire scepticism • Lack of knowledge	• Small market, missing support chain • Fire scepticism • Lack of education
Situation today	• Have to sell glulam and service	• Scepticism towards glulam	• Environmental interested people use it	• Design with environmental structure
Future	• Good, since prices of competing materials are rising.	• Use glulam together with other timber products.	• Increase of small spans, more competition in large spans.	• Education is needed

4.2.1.1 Austria

The different segments are the different applications; housing, industrial, community and bridges. The market share in mid Europe for glulam is about 10 % and it is higher in housing. The market share is assumed to be growing in the future. According to another view of this, it is said that the extraordinary constructions are the only important segment here. The

advantages of using glulam are the advantage in fire, the weight and the ecological arguments. The last mentioned arguments are not something that the costumers will pay extra for now, but it is a good aspect for choosing the material. The other person said that the environmental aspects are not interesting when selling glulam. It was then said that the difficulties of selling and using glulam is to show the equivalence of the end use. It has to be shown how glulam should be used, how to calculate and how to work with it. It is not enough to show a building that has glulam beams, because the architects and the engineers want to know how this is made. This increases the importance of competent persons when talking about glulam and when selling it. The problem with this is the lack of education about glulam and wood in the engineer and architect educations in Austria too. Today only a minor part of the architects are working with the material. Today the people working at the construction site are not familiar with the material and they usually work with big construction companies who want to optimize margins. Since the steel price has risen, the companies are getting more interested in glulam for economical reasons. The difference of selling glulam and other material is that the one that are selling glulam has to give the whole service, they have to have the engineering know-how. If you are selling concrete or steel, they do not need to have the knowledge themselves since the users know how to calculate to get the construction right for example. Since these materials are much more known, the glulam sellers has to provide the buyers with the knowledge they do not have about how to work with the material. The fact is that glulam is used less than it could be used, so there is a potential for market growth. The potential use in the future is increasing mostly since the price of the competing materials is rising.

4.2.1.2 France

The different segments of glulam can be divided according to the size of the span. Residential buildings are mainly small, one family-houses. Non-residential buildings are gymnasiums, factories, supermarkets, agricultural buildings and community houses. Also bridges are mentioned, but the amount is small. In France, large buildings like supermarkets, gymnasium and factories have about 80 % of the market share for glulam, 20 % of the buildings are agricultural, 2-3% are residential houses and about 1 % are bridges. Overall, glulam applies about 5 % of the building market. The potential market share for glulam in gymnasiums are 15 %, in warehouses an increase from 1 % to 5 % has taken place in the latest 10 years. 2-3 % of the concert halls that are built now are with glulam. In France, glulam is well known and well accepted by major companies. It is good for long span buildings and it is good for fire resistance. The latter must be mentioned often since a lot of people think it is the opposite. Another answer was that the advantage of using glulam is that it is good for the environment. The disadvantage of using glulam is the lack of knowledge of calculating with and building with glulam. The carpenters are accustomed to work with concrete and the concrete industry is very big in France. The industry is supported from the ministry since it is such a big employee in France. The French people like their houses to be stable and they are associating this with concrete. It is a traditional stone and concrete building country, so it is difficult to get the French to accept that glulam also can be used. Another view of this is that people started to build with wood in the 70's. The look of the wood is not so good anymore. This makes people sceptical about using wood. The treatment of the beams is also a big issue. It was also emphasised that the building regulations do not apply for using wood, which makes it more difficult to use and to sell. About 90 % of the spruce used in the French glulam production comes from Sweden.

The architects that use it today are the wood architects. The other architects do not know how to calculate with glulam beams. In the 70's they started to use glulam in the big beams and in

curved constructions. Glulam is used since it can be curved and for the clear span. The architects are also a bit worried about the glue in the glulam. It is about the same question as in Japan with the air quality. Today it is quite courageous to use glulam if you are an architect. The carpenters and the people on the construction site have no problem with the material. The potential in the future is considered to increase. It is important to realise that glulam is one product in the timber conglomerate, there are other engineered products that can be used instead of glulam like duo and trio or cross-laminated timber and so on.

4.2.1.3 Germany

The different segments of glulam are two main parts: housings up to 10 meters and warehouses with curved beams up to 50 meters long. The spans are usually 25 to 40 meters. These industrial buildings are usually made in smaller factories that produces between 5 000 m^3 to 50 000 m^3 a year. The producers of the beams to the smaller buildings are usually large factories that produce straight beams and the capacity of the factories are about 100 000 m^3 to 200 000 m^3 a year. The raw-material comes from spruce in Germany or in Austria. The raw material production might be a problem in the future, since the younger forests are mainly broadleaf. Therefore there are some experiments with glulam made of beech.

Today 14 % of the buildings are wood constructions. Most buildings have some timber in them. Glulam are also used together with steel and concrete, for example steel and concrete in the foundations, then glulam framework. Another answer was that the residential houses are not the right place to use glulam, it is better in larger constructions, such as factories and in larger buildings.

The advantages of using glulam in housing relate to the environmental aspects. Better insulation and it takes a shorter time for building it, which lowers the costs. Usually the people choosing to build their house with a wooden frame are more aware of the environment and they have chosen the material. They are better paid and can spend more money on their house. The advantage for the industrial buildings is the price. The disadvantage is that people think that glulam is worse than other materials according to fire resistance. Also the fact that the timber degrades is a bad thing, and therefore preservatives are used. The other answer to this question was that glulam is good and the material is available. The carpenters like the material and it takes less time to work with. There is often a local feeling when choosing glulam. There are several soft arguments since it has this local production and it is a dryer building site for the carpenters.

The architects do not have the knowledge about how to use the material, the same problem occurs with the engineers. This increase the planning work for the projecting companies since they have to see if the calculations in the joints are right or not. The architects who know about glulam respond positively to using it since it has a nice, positive feeling. Most of the people working at the building site are used to work with concrete and if they have used it, it was used in the roof frame.

The potential in the future for glulam in housing is up to 40 % of the timber market. This would be an increase of the small spans and straight beams. For the larger buildings there is more competition. The steel industry has improved their quality with high-stress beams. The concrete industry has improved their fire resistance. The competing industries of glulam try to take advantage of the building regulations so it is more difficult to use glulam. The other answer to this question was that the potential for market share will increase if the knowledge that glulam can be used and how you use it, is satisfied.

Glulam is used in areas where earthquakes can occur like in Japan. Therefore a lot of glulam has been exported to Japan from Europe.

4.2.1.4 United Kingdom

The different uses are mainly in buildings for education but also sport and leisure (mostly swimming-pools), community buildings, less commercial buildings. In UK about 2 % of the frame constructions are made of glulam. It is getting more popular mainly because of the environmental thinking and that the price of steel is rising.

The advantages of using glulam are that it is renewable and captures CO_2, the performance of the product during fire, you can construct a bridge indoors and transport it to the construction site, and glulam can be curved and extended and cut if required. It is easy to use. The disadvantages are mainly that people think that it will burn. The market in England is small, this makes it expensive. If larger product volumes would be used then the price would go down.

The architects that have the knowledge about the material like it. One reason is that they can design with environmental structure. The knowledge about glulam within architects is not so good. The main builders are familiar with concrete and steel. When glulam is used in a building, the support chain is missing since the constructors are not used to work with it. To increase the use of glulam, education is required.

4.2.2 Use of glulam

In table 4.2.2 a summary of the interviewee's answers are given about who produces glulam in the country, the use of glulam and their opinion about the situation today.

Table 4.2.2 Comparison of answers from interviews according the use of glulam.

	Austria	**France**	**Germany**	**United Kingdom**
Production of glulam	• Sawmills • In 2007 almost 1.4 million m^3 (EUWID, 2007)	• Traditional builders • 150 000 m^3/year • promote GL 24	• Sawmills[3] • In 2007 almost 1.4 million m^3 (EUWID, 2007) • GL 24 or GL 28	• No production
Use of glulam	• About 230 000 m^3/year (EUWID, 2007)	• 200 000 m^3/year	• About 1 million m^3/year (EUWID, 2007)	
Situation today	• Growth in consumption and probably production in	• Unfair insurance-rules	• Europe exported abroad earlier,	• Educational buildings most common with

[3] According to some interviewees outside Germany

	former Eastern Europe • Different interests in the chain forest owners -glulam salesmen		not anymore	glulam frame

4.2.2.1 Austria

The largest consuming countries will probably be the former Eastern Europe. This growth is however slow. Probably they will start to produce glulam if the production is connected to sawmill production. Another view is that there will be no production in Eastern Europe except for maybe in Russia. Interviewees from other countries had said that the largest glulam factories are located in Austria and in Germany. The people interviewed in Austria did not answer on the question of which country produced most or had the largest production sites. But one thing they commented about it is that the production capacity is too large in Europe.

The largest market in Europe today is Germany. The market for construction has a limit and the glulam consumption is depent on how much building is planned. It is growing compared to other material in countries like Spain and Italy. In Italy the building will decrease because it has reached the limit, now there are empty houses because of overinvesting earlier. In the future it is anticipated that the biggest markets still will be in Germany.

The larger industries come from the raw-material side, in other words, the sawmills. To understand where the glulam market is in the chain, see Figure 4.2.2.1 below.

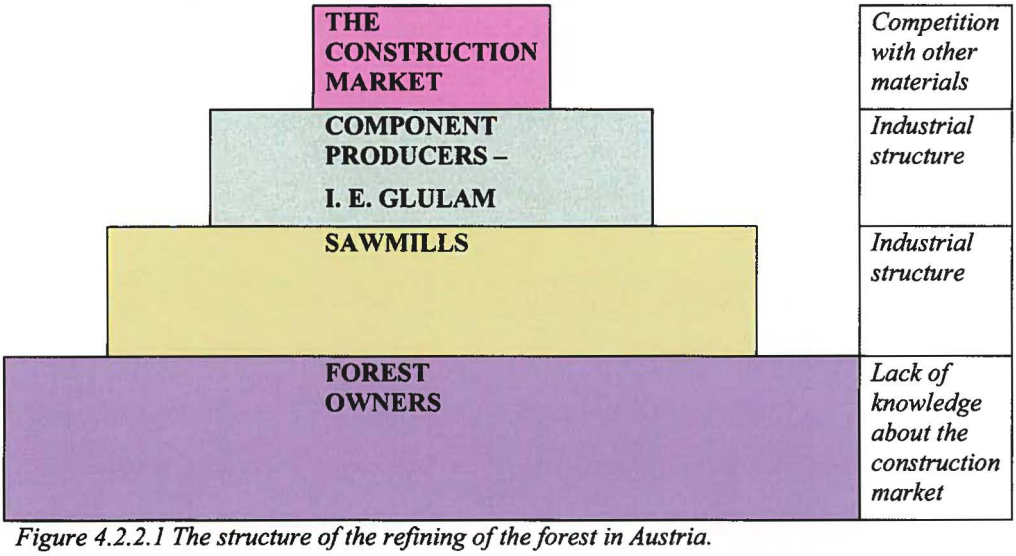

Figure 4.2.2.1 The structure of the refining of the forest in Austria.

The forest owners are a large group and they want to increase the price of wood so they will obtain greater returns when selling the forest. They do not have any knowledge about the construction market. Unlike the forest owners, sawmills want the wood to be as cheap as possible since they are buying it as a raw material for their production. The component producers can be connected to the sawmill and both groups have an industrial structure. This means that they have a production focus and are also not aware of how the construction market is, they want to sell as much as possible. The smallest group is the construction market. Here the competition with other materials take place, here they have to hire engineers to show how glulam should be calculated and worked with. Here the best solutions have to be shown. As the interviewee said; "the peak is weak" and was then referring to that the real competition is here. They are working with the solutions and can combine different materials like steel and glulam to get the best solution. The construction market wants to have support from their suppliers and the forest owners so they can work together and to optimise the production of glulam.

4.2.2.2 France

The strength class will be GL 24 or GL 28. It is easier to produce GL 24 in France since the quality is inferior and the lamellas are then cheaper. It is easier to find the material for producing GL 24. The consequence of this is that GL 24 is promoted.

In France, the glulam producers are traditionally builders. This is a difference compared to other countries where the sawmill industries have increased its production steps from just making boards and now are gluing them together to a beam. The producers in France do know how to use the products they are selling. In this country, you have to guarantee that the buildings have insurance for 10 or 30 years. For 10 years the guarantee is that there will be no defects, for 30 years the guarantee is against collapse. This can be compared with Germany that has to guarantee the building to last for 5 years and in the UK for only 2 years. The insurance cost in France is about 5 % of the whole costs.

For the last 10 years, about the same countries have been using glulam as today. It is difficult to get carpenters that know how to work with glulam. In France, the knowledge from older generations that worked with wood disappeared during the First World War. The carpenters got the task to work with the trenches, and a lot of them were killed during this War. The consequence of this was that the knowledge of how to work with wood disappeared.

In France, they are using about 200 000 m^3 each year. The production in the country is about 150 000 m^3, the import is about 40 000 m^3 and it is mainly short straight beams. French glulam producers also export about 10 000 to 20 000 m^3. The production in France that is used by them is about 10 000 m^3 small straight beams, 60 000 m^3 building kits which are arches that is projected and are sold to carpenters. The biggest part is 80 000 m^3 and it is peaces that are prefabricated.

4.2.2.3 Germany

The ordinary strength class in the future will be GL 24 or GL 28. The GL 32 is for more advanced buildings and is difficult to produce in Germany. The smaller production sites mainly produce GL 24 and these beams just need visual grading. They are easier to produce.

The largest glulam producers in Europe are considered to be in Austria where the individual production sites can have a production of more than 200 000 m^3 a year. In Germany some

sites have a production between 100 000 and 200 000 m^3 a year. The largest producers are not in the glulam organisations, so it is difficult to know their real production. The production during the last years in Europe has been about 5-6 million m^3 a year, earlier it was 2-3 million m^3. Germany has exported a lot to the United States. Japan has been a country where Europe has exported a lot, but a lot is changing. The largest market today could be either Germany or Italy. In Germany the southern parts are the traditional wooden house building part, which makes it easier to use glulam there.

4.2.2.4 United Kingdom

The companies that the architect that was interviewed knew had been in UK were Finnforest, Lillhayden (Danish), Schillegar (Swiss). It is important with products and services since it is not a very common material to use, and Wiehag (Austria) for example offers this.

A lot of the glulam producers are interested in the UK-market since they are spending about 2 million Pounds on educational buildings every year.

4.2.3 Forecast

In Table 4.2.3 a forecast of the market share and the influence of environmental aspects are summarized.

Table 4.2.3 Comparison of answers from interviews regarding the forecast.

	Austria	**France**	**Germany**	**United Kingdom**
Forecast of market share	• Hard to tell • Lack of know-how can lead to quality problems when using glulam	• Market share about the same proportion • Increase of industrial and storage buildings	• North America, Scandinavia and Austria will compete • In Germany and Austria the more advanced buildings will increase. • Increase in France, Spain, UK and in former East Europe	• Use of glulam will increase
Influence of environmental aspects?		• Glulam can increase its market share since it is less energy demanding	• Uncertain	Much, the government is calculating CO_2-emissions

4.2.3.1 Austria

The knowledge about glulam is not so well spread as wanted. This can lead to quality problems. The reason is that the users that do not have the knowledge might use it incorrectly, and the material might then last less time than it should or you have to change parts that you should not have to do. This makes people believe that it is a difficult material to work with or a bad material.

Today the standard product is standard beams. They are produced by sawmills, and they do not know the market since they are selling the beams to the retailers. Sawmills can not predict the building sector since they have no connections there. They are just producing as much as they can.

4.2.3.2 France

The market share of the different segments will continue and will have the same share as today, but the industrial and storage buildings segments will increase because of the fire resistance. One other view of this is that buildings with middle span like gymnasiums will increase when the time is close to elections in the municipality. The reason for this is that the politicians then will show that they are caring for the people living there and want to build these buildings with environmentally friendly material.

Glulam compared to other material can increase in the future if the environmental aspects become more known. This can lead to an increase from 5 till 10 % of the market share. As said from the other interviewee, the producers cannot affect this increase, but it is a good thing that the demand is oriented towards wood since it is less energy demanding when it is produced. On the question if the use of glulam will increase, one of the interviewee said yes, the other said that it would not increase so much. If it will increase, it is thanks to the environmental aspects.

4.2.3.3 Germany

In the future, North America, Scandinavia and Austria are the competing producing countries, according to one of the interviewees' forecast. The other forecast is that Germany and Austria will still consume much glulam and the more advanced buildings will have an increase here. The increase will be in France, Spain, UK and the former Eastern Europe like Poland. The environmental aspects can change this. The other interviewee said that how and where the different markets will be and the size of it depends on the transport and energy costs. It was also said that it was uncertain to say that the environmental issues will influence the use of glulam and the market shares.

The forecast is that the markets will be stable in Europe. An increase of the glulam use can also occur, the same with other glued products. If the former Eastern Europe will increase its use of glulam more, companies from Austria for example will continue to increase the production where it is consumed. They have already glulam companies that are located in the Czech Republic and Hungary.

4.2.3.4 United Kingdom

In UK the use of glulam will increase. In commercial buildings more than three floors, cross-laminated timber will be used. In buildings less than three floors, educational and smaller buildings the use of glulam will increase. The reason is mainly that the use of timber is good.

The government is calculating carbon emissions and they are using climate calculations. The awareness of the climate change is widely discussed and it is said that it is important to act now since it will be a bigger impact in the future of ignoring it.

4.2.4 Glulam Market

In Table 4.2.4 the SWOT-analysis and PESTEL-analysis are summarised.

Table 4.2.4 Comparison of answers from interviews regarding the glulam market.

	Austria	**France**	**Germany**	**United Kingdom**
Strengths	• Environmentally friendly • Fire resistance • Light material	• Higher reliability compared to timber • Environmental issues	• Weight • Environmental aspects • Easy to machine • Fire resistance	• Environmentally friendly product • Easy to use
Weaknesses	• Market not well organised • No focus on the competing materials • Transport of raw-material • No technical solutions	• Appearance from the glulam used in the 60's to 70's • Transport of raw-material • Less developed computer software	• Do people care about the environmental aspects? • Glue-scepticism • Architects do not know about it • Not well-explained	• Size of the market makes it expensive
Opportunities	• Safe standard solution • Good pricing • Bring the value-chain together	• Hopefully same Eurocode in the European countries • Increase of knowledge	• Local aspects • Willing to pay for more if interested	• Environmentally friendly, but more education is needed
Threats	• Competing materials uses other ways to compare the material • Volume produced in Europe has to be consumed here when transport	• Sound insulation is bad • Scepticism towards the glue (air-quality)	• Population development • Glulam not recycled • Not one voice from the producers	• Perception, since it is an organic material • Sell as a system, not a product

	costs are rising			
Legislative and Political trends	• Tell politicians that glulam is a good and safe material	• Obligations to use a larger amount of timber in the buildings	• CE-marking • Political debate about CO_2 good • Debate about VOC and formaldehydes bad	• Knowledge about the environmental aspects are increasing which helps • CO_2-aspects and energy helps
Economic trends	• Organisations between countries can unite different wants, economic values will be added.	• Price of competing materials influence the use of glulam • Glulam producers have been bought by concrete companies	• Small sawmills more specialised • Larger sawmills more product-oriented • Steel price rises	• Steel and concrete producing countries now need the material more themselves
Social trends	• Today more used in the countryside and for elderly people	• Younger people more open minded • Late to realise the environmental aspects	• More popular with wealthier people • Wooden houses more popular in southern Germany	• Big health trend, glulam is a healthy material
Technological trends	• Combine cross-laminated timber with glulam	• Treatment of timber • The glue • Software	• Already much is known about timber, but not many know about it	• Long span structures • Important to sell glulam as a system

4.2.4.1 Austria

The strengths: Environmentally friendly, fire resistance and a light material.

The weaknesses: The glulam market is not well-organised and the standards are not as developed as others. The standardization is driven by the forest owners in each region and they want to sell their own products. There is not just one market like in steel; there are several markets since they are produced locally. The focus now should be that the consumers and architects should choose glulam instead of steel and concrete. The focus should not be to choose glulam from a certain region, this makes the consumers confused. The weaknesses told by another interviewee are also the transportation because of the more environmental focus. There are no solutions how to use the material which makes it difficult if someone wants to use it. There is no cooperation to the new markets that they are entering. Today some

of the carpenters are using it, but they do not have the knowledge of how to use it. This is a bad thing were the consequences are already seen.

The opportunities: To have a safe standard solution and a good pricing. It is easier to calculate when you have the standard beams but it is difficult when you have other constructions. There will be a good thing if the industry are working together and bring the value chain together. Today the value chain is more focused within itself and is ignoring the steel and concrete industries which are the real competitors. Each country has a value chain and all of these value chains are too much to add together. It must be connected to have just one message so the potential users will understand it. Today several different value chains mean a lot of problems since there is a difficulty to cooperate. The cooperation should first of all start within the countries and then between the countries to have a good chance to compete with the concrete and steel industry.

The threats: Steel and concrete say that they are better because concrete last longer and that you can reuse steel. Therefore the environmental aspects are difficult to use with glulam when there are other ways to compare the materials.

Transportation is still inexpensive. If this will change because of the transport tax, the volume produced in Europe has to be consumed in Europe. This means that the consumption has to rise here to continue to have the same prices and quality.

Glulam can be used only if the engineers show that it is a good material to use and how it will be used. The engineers have to show the solution of how to use the material. Marketing is not important to increase the use of glulam if the engineers do not show the solutions.

The political trends: It is important to tell the decision makers that glulam is a good and safe material. Otherwise the risk is that the concrete and steel industries tell the politicians not to use glulam. It is important to try to actively advertise that glulam is quality building, and then glulam has good chances.

The economic trends: If the organisations between the countries succeed to unite the different demands in the industry, then it will increase the economic value to the glulam industry.

The social trends: Today glulam is more used in the countryside than in the cities. It is also used when building for elderly people, since it is brighter. Therefore there is an emerging potential for use of glulam in constructions in urban areas.

The technological trends: Cross-laminated timber gives new chances when it is combined with glulam. As said before it is very important to invest in engineers because when using glulam you have to explain more than if other materials would be chosen. It is the same things in all projects, more explanation is required.

4.2.4.2 France

The strengths of glulam are that the reliability is higher if it is compared to traditional timber. The span is also larger than using timber. Glulam is considered to be stronger than timber. By the ones that are familiar with it, it is considered to be a safe material. The other interviewee said that the environmental issues are the strength.

The weaknesses are the look of glulam today from the beginning of the use of glulam in the 1960's and 1970's. The buildings were then built without any protection and glulam was used on the exterior. Today the buildings have a problem with fungi. These buildings are therefore

reconstructed the way glulam should be used. Today treatment has improved, but it is difficult to convince people who have bad experience.

The transport is an increasing weakness, since 90 % of the lamellas used in the glulam production are imported from Sweden. The transport is influencing the Life Cycle Assessments much, which means that France should use more of the domestic material. The quantity is too small for this.

Since the concrete industry is dominating the building market in France, they can afford to have the best civil engineers, they have developed good technical aids to help the design engineer and others that need help. Since the glulam companies are much smaller, they have not got the same money to develop help with the drawing in computer programs for example. A lot more engineers work in the concrete companies than in the wood companies. As a comparison, of about 1000 just graduated engineers that were looking for jobs in the building industry, only 15-20 started to work with timber construction.

The technical aspects are a weakness since most of the engineers and architects do not know how to calculate when building with glulam.

The opportunities: There are different rules in different countries which makes it more difficult to export products and knowledge from one country to another. In 4 to 5 years time Eurocode can be real. When Eurocode is used and the knowledge has increased, it will hopefully increase the use of glulam. Building with wood is a niche market, and this market is considered to be non-common. It remains to be shown that the material is good to use in buildings. Today masonry workers do not understand the carpenters since they have different backgrounds.

The threats: The sound insulation is a bit bad. The other interviewee said that the glue was a threat since people think that it is bad to have it in the buildings. The users fear that the air quality decreases.

The legislative and political trends: CE-marking, CE is the French letters for European Conformity. In France they are obliged to have a small amount of timber in the buildings, this amount may increase in the future. The politicians will perhaps advocate timber use since it is absorbing CO_2 when it is growing, but the concrete industry is supported by the French government and the concrete companies do not want these environmental aspects to be considered. REACH – the new European community regulation on registration, evaluation, authorisation and restriction on chemicals tells which chemicals should be used or not.

The economic trends: The price of the raw material influences the glulam market. So do the price of energy, transport and also the price of the competing materials like concrete and steel. Today in France, some concrete companies have bought glulam producers. In this way the concrete companies can decide when glulam can be used, because it is their decision. This makes the competition more unequal since one side can decide when the competing material can be used or not. This makes the cooperation within the glulam industry more difficult, since some of them are owned by the competitors.

The other view of this was that glulam is starting to be produced in the former East Europe. For example for some years ago, Poland imported glulam. Today they have their own production. Today the glulam beam can be transported 500-700 km, but in the future with higher taxes on transportation, this can be difficult since the costs rises.

The social trends: Younger people are more open minded to new things; they travel more and have seen other ways of living and other houses to live in. The consequence is then that

younger people accept timber houses easier. It is also important to realise that the different countries have different view of the material, and this makes it difficult to promote glulam in one country the same way as in another country. For example, France has not yet realised the environmental aspects.

The technological trends: The two interviewees said that the treatment of the timber is very important, that it will be environmentally good and also effective. The treatment is obliged to contain water, which means that it is less effective. The glue is considered to have an impact on the atmosphere in the building where it is used as beams, which makes the potential users afraid of using it.

The software used when building in glulam is also a problem. The drawing and the calculation are not integrated. This leads to a lot of time used when drawing and calculating in glulam which is not the case when building in concrete or steel. The technical solutions are also important aspects, if you have a ready solution, it will save time. It is also very important that the potential users know how to use it, know how to calculate and so on.

4.2.4.3 Germany

The strengths: The weight, the environmental aspects, glulam is easy to machine and has good fire resistance.

The weaknesses: The question is if people care about the environmental aspects like the storage of carbon in the glulam beam and the energy effective production of the beam. There is an insecurity if the glue is healthy or not because of the formaldehyde and other VOC[4].

In Germany, there are a small number of companies that are small and medium sized enterprises. Most of the architects are not aware of the products available to them as they do not see any advertisements for glulam for example.

There are very good tools for working with concrete and steel. Timber is not well explained, and is not considered to be user friendly. The architects and engineers must get help when working with glulam. There are a lot of small timber associations. Most of them are sawmill associations. They are not interested in the end use, just to sell their products.

The opportunities: If the market share of glulam would only be a little larger, the consumption would be doubled. The local aspect is a good thing, since glulam is produced from the forests nearby, this gives another dimension to the building, one interviewee said. Wooden houses have increased and the group who wants these houses is willing to pay more.

If you compare the transport between glulam and steel, the distance is shorter for glulam. Steel is often imported from China.

The threats: The development of the population is not good for the market since the ageing population does not build new houses. As a result of this, building decreases by 45 % 2006. Today, less new buildings are needed; renovation is forecasted to have a larger share in the future. It is the same in the whole of Europe except in the Southern and the Eastern part.

Glulam is not recycled, which for example steel is. This makes the outlook on glulam negative.

The glulam producers do not have one voice.

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[4] VOC is Volatile Organic Compounds. Aldehydes are an example of this group of organic chemical compounds.

The legislative trends: The CE-marking helps the producers to sell glulam, but it does not help the one using glulam to build.

The political trends: For the glulam market it is positive with the CO_2-emission debate since the awareness of minimizing CO_2 is increasing. It is negative with the environmental aspects of the glue with aldehydes and VOC. Also the increase of firewood to make energy influence the glulam market, since the price of wood then increases. Unfortunately other industries are lobbying to influence the building industry against glulam. For example they are accusing the glulam industry of having too much to say in the industry and are saying that glulam is not a good material to recycle and therefore it is not environmentally friendly.

The economic trends: In the near future the small sawmills will be more specialised. The larger saw-mills are more product oriented. The price of steel will increase which makes concrete more competitive and hopefully glulam too.

The social trends: Wealthier people like to use ecological products. Since glulam is more locally produced, it is becoming more popular in this group. In the southern Germany it is popular with wooden houses, in the northern parts people want to have more traditional brick buildings.

The technological trends: The use of timber products is not easy and it is difficult to avoid that it will be too technological. Glulam can be used as flooring directly, and also as rafters if one avoids drilling holes in the beam to avoid cracks.

There are already a lot of things that are known about timber however this knowledge is not available for everyone. The customers are the key factor. If they are afraid of using glulam, then no one would use it. There are problems then when some building collapses because the calculation was wrong. The public believe that timber is not a very reliable material, and do not want to use it. Therefore the image of the reliability has to increase.

The environmental trends: It is difficult to meet the questions about the formaldehyde and mould. There are problems with the preservatives since they are not as efficient as when they were less environmentally friendly. There are also problems with the lobbying from other materials. The brick industry compares their products after the production. The same problem exists in the steel industry. Therefore there are discussions about what steps regarding the production that should be taken into calculation when comparing the materials.

4.2.4.4 United Kingdom

The strengths: Glulam is environmentally friendly and easy to use.

The weaknesses: The size of the market makes glulam expensive.

The opportunities: Environmentally friendly, but more education is needed.

The threats: The perception, that it is an organic material. The system should be changed, since glulam is a product and not a system. It should be more like a system.

The legislative trends: It helps glulam especially in the future since the knowledge of the environment is increasing.

The political trends: The politicians are very interested in how much carbon the production is using. When glulam is produced, less energy is used compared to steel and concrete. Glulam also embodies carbon.

The economic trends: Countries (like China) which are now supplying much of the market for steel and concrete. The public are getting wealthier and can build more which influence the other markets.

The social trends: Health is a big trend now, and glulam is a healthy material.

The technological trends: Today it is good with some interesting innovations like long-span structures. Here steel is competing. It should be better if the big producing companies saw glulam as a system and not a commodity.

The environmental trends: This trend is good for glulam. It is important to show how and why timber is good because those that might choose to work with it want to know this.

4.2.5 Comparison

Table 4.2.5 is a summary of answers to questions about what will influence the use of glulam, the durability, perception, who influence the choice of material and how to increase the consumption.

Table 4.2.5 Comparison of answers from interviews regarding a comparison between different materials. Note that the answers differ some within the countries since more than one are interviewed.

	Austria	**France**	**Germany**	**United Kingdom**
Influence the use	• Standards • A whole solution for using glulam • Focus on which markets are wanted	• Easier to calculate and use concrete and steel • Habit and tradition	• Massive timber structures more popular • More knowledge about concrete and bricks	• Environmental thinking • Work with hybrids
Durability compared to other materials	• Do not know, if used right it will last very long • Today mostly used inside • Outside concrete lasts longer	• Considered longer for concrete	• Glulam not comparable when used outside • Glulam used the right way, no disadvantage • Concrete not as long-lasting as sayd	• People think that glulam and steel last longer • Glulam easy to reuse, have to knock down concrete, steel has to be re-melted to be used again
Perception	• Vary depending on size of building, has to be explained	• Today extraordinary to use it	• People think that concrete and steel are more durable • Negative	• The public love timber but is afraid of degradation • Initially more

			thoughts from timber-barracks after the war	expensive, but cheaper to work with
Which material is used?		• The architect decide if not any special requirement • Glulam chosen when aggressive environments • Tradition • Price	• Architect decides but customer can decide • Price is important • Technical characteristics important	• The architect use the material he used the last time
Increase use of glulam?		• Information about its existence • Use of wood is positive • Better to promote bigger buildings with glulam • Bad with the noise-problem	• Do designing in glulam more easy • A solution to avoid cracking • Increase knowledge • Different needs in different areas	• Important with system design • Increase education

4.2.5.1 Austria

The best influence on the use of glulam is to obtain standards, and also to show the solution of how to use glulam. Also important is not to make cheaper products because then the quality will be reduced, rather concentrate attention on markets you want to have and then focus on them.

The decision of choosing one type of beam is mainly based on tradition and the lack of knowledge of using other materials. Glulam is sometimes a better material and if the price of other materials rises, then glulam will have a better chance.

About the comparison of durability, the answers were different. One of the respondent said that we do not know how long glulam last compared to other materials. Also that glulam today is mostly used inside the buildings, but outside glulam and concrete are not in the same level (meaning that concrete last much longer). Another answer was that if you use glulam the right way it will last longer. This depends on the know-how, how safe and long-lasting it is.

The perception from people is varying depending on the size of the building. When the building is large, they are a bit sceptical. The reliability and safety has to be explained. 10 years ago, a span of 70 meters was maximum, now it is bigger. Since the large spans have increased during the latest years, this has to be explained more and more.

4.2.5.2 France

The competing materials in housing is mostly steel, in public buildings steel and concrete, in agricultural buildings it is steel, in supermarkets steel or concrete and industrial buildings mostly steel. For small bridges the competition comes from steel, in larger bridges the competitor is concrete. The advantage of using concrete is that it is stable from the ground the fire resistance of concrete is good. Steel beams' size is smaller than glulam beams when they carry the same weight. It is easier to use both of these materials compared to glulam since it is easier to calculate and draw for it.

The durability is considered to be longer for concrete, and that it is better to use outside than glulam and wood. In France they are accustomed to building with concrete, so both the builders and the public are sceptical towards glulam. The preservatives are a problem with glulam. In France, the guaranties for 10 and 30 years are the same and are not dependent on the beam material. The insurance companies like glulam because of the fire resistance, so it is not a disadvantage of using glulam. When a bridge is built, it is calculated that it will last about 100 years. For houses it is 50 years but in reality it is also for 100 years. For wooden noise barriers it is calculated to last for 25 years. To make the material last longer, preservatives are used. Today only one company is providing the preservatives. Hopefully there will be more companies in the future, so there is more to chose between. More research can then be made. You do not want the material to degrade, since it also will lose its strength. But if you have to replace a glulam beam, the old one is often reused in some other building, used as panels or you burn it.

The architects select which material will be used in the building if there are no other requirements from the client. It is also a question of the economical aspect when choosing material.

To produce glulam, less energy is used than when producing the competing materials. Concrete is more locally produced, but is more expensive to produce. Concrete is also prefabricated which makes it more easy to use. The publics view of the different materials is that wood is weak and concrete is hard and trustworthy. Stone is the best building material. Wood degrades and it is considered to be extraordinary when it is used. Glulam is beginning to be used in gymnasiums, which makes people slowly aware of the option to choose this material. But it is a slow process.

The price of the different materials in France is the following; steel is about 20-30 % less than glulam, concrete is about 5-10 % less. In the future it will be about the same, the interviewee guesses. Glulam is considered to be a competing material in the middle span buildings, like gymnasiums. It is also considered to be competitive when the surrounding is aggressive, like factories and swimming pools. Then glulam is chosen not just because of its environmentally acceptable aspects. The reason for choosing one type of material is the price or in which part of the country you live in, what building tradition you are used to. Since it takes longer time to prepare to build with glulam than other materials, the decision is not difficult to make.

The use of glulam could be increased by informing the potential users of it so that they know how to use it. Also the traditional users will know about it. The major companies are the key to this.

The transportation flow will change because of the environmental thinking of long distance transportation. But it will not change rapidly.

The credibility of glulam is important. It has been used for about 100 years, so it can last a long time. There are a potential of mixing wood and other materials, to use each material according to its properties.

The feeling of wood is nice when you touch it, and it has been alive. You are using it when you make a fire, so it has a good perception.

Cutting wood was considered to be negative, but it has to change. There is a certificate for sustainable forestry.

One big development is promoting glulam in industrial buildings since it is large buildings and it is good for the environment. Earlier the promotion was for housing but it was not so successful. The problem with timber frames is the noise, and there are no good solutions.

4.2.5.3 Germany

The competing materials are for large spans pre-stressed concrete and steel. For housing it is concrete and bricks. Multiple housings in glulam are neglectible. The massive timber structures are more and more popular in Germany.

The advantage of using bricks and concrete is that everyone in the building sector knows how to use it. For steel it is the same. The traditional timber frames do not have solid walls of one material. It is better when cross-laminated timber can be used together with the glulam beams. One disadvantage is that the building site is very wet in the beginning when building with concrete and steel. Also the fact that the building takes longer time when using these materials instead of glulam is a disadvantage. The insulation in the brick buildings is also good.

The durability of concrete is not as long as said. The everlasting concrete bridges are not everlasting. The concrete is often reinforced with iron inside. The iron is exposed even there and corrosion is the consequence. The distance from the steel to the margin of the concrete beam is important for how fast and how much corrosion the steel will undergo. The other interviewee said that the durability is not comparable between glulam and the competitive material. This is when glulam is used outside, inside glulam will last longer. The problem is the cracks that can come up when the wood is drying or if the humidity in the surrounding environment changes much. The cracks will then influence the shear strength.

If glulam is used the way it should, there are no disadvantages of using glulam compared to the competing materials when comparing their lifetimes. The problem is that there are many steps in the process where it can go wrong and this will influence how long the material will last. The knowledge of how glulam should be treated and used is therefore important. The other interviewee said that the different materials can last for 50 to 100 years, but it differs from the climate, it is a good thing if salt is used in the winter on bridges. The salt kills the insects that can be attacking the wood. The salt has to be NaCl, if there are some other element than Sodium (Na), the properties of the glue might be influenced.

The environmental influence on the preservatives makes it not efficient enough. It is better to use glulam built-in or indoors, so it is not influenced by the rain and the sun, this will prevent cracks, insect attacks and deterioration of the wood. The most important thing to do to look after the glulam beams is to have a look at the beams each 5th or 10th year to see if there has been cracks. This is extra important in the larger buildings. To increase the lifespan and durability, glulam can be heated to get a more resistant surface.

On the building site, glulam is more easy to use, but it is easier for the architects to design with concrete and steel. It takes much more time to design wood. The other answer to how

easy the different materials are to use was that there are good tools for steel and concrete. The knowledge of timber is isolated to a few places, the material is not well explained. The engineers and the architects do not know how to use it, therefore the company that are building with glulam has to control that the calculations are right. One common incorrect way of calculating, is to assume that the joints are fixed when building with glulam. The engineers calculate this way when using concrete and steel, and do not know it is different when using glulam.

To produce glulam compared to the competing materials, it is less energy demanding. Timber based products are the only group that is reproduced. Steel for example is recycled, but in fact it means down-cycling.

In Germany the public think that concrete and steel are more durable. Therefore the glulam use is questioned if they will use it themselves. People use wood for fires. They think that glulam is more risky to use since there can be a fire situation. In Germany, barracks were built for the homeless after the war. These barracks were cold in the winter and very warm in the summer. It is also known that the sound insulation is bad in wooden houses. After this the Germans have been sceptical to using wood as a building material. This is the case especially with the older people. Since younger Germans travel more and more, they see houses in other places and see that wooden houses are a possibility. The green architecture has become more popular now.

The steel price is rising compared to glulam. The steel producing companies has increased their quality also in smaller spans. This makes architects choose steel even if it is more expensive. As housing goes down in the future, the prices will decrease.

Glulam is considered to be a competitive material in housing. In the industrial buildings it is just a matter of how much it costs. The other interviewee said that in Germany the environmental aspects are not so important yet, mostly the price influences the decision of which material to use. As the awareness of the environmental aspects will increase in Germany, so will the glulam use. The customer is also very important to teach about the material, since he/she can say which material they want. Timber has a nice feeling when using it, and this is mainly used today in the wealthier homes. There are also examples of buildings where glulam is used because it has the best economical or technical characteristics. In some cases the glulam beams are even painted so it is not shown to be glulam. In many cases the beam is shown as it is since it is considered to be beautiful.

An architect is choosing one type of beam because of the price especially when it is an industrial building. When it is housing, the span and the knowledge of which material that can be used is important. Also the relationship with the customer and the wishes from that side has different influence of the choice.

To increase the consumption of glulam, it is important to make the desig of glulam easier. It is also important to find a solution to avoid cracking. Higher moisture content when using glulam inside is not a problem. The problem is when the moisture content is to low, and then the cracks will appear. This can be the case in some production industries. The other interviewee said that the knowledge problem is the main issue. Knowledge in different areas has to increase. For the material it is about the cracks in the glulam beams and how to deal with the climate changes. It has to be easier for the builders to use the material and to calculate factors correctly. This is not just important so more people know that it can be used and how, but also to avoid mistakes. Bad knowledge leads to bad examples. The political actions that can be made are to stimulate an increase of the green buildings, like the United Kingdom has done. Another important thing is to participate in the different environmentally acceptable industry groups. Concrete and steel participate, glulam is represented quite poorly.

For example the recycling issue is discussed here, and glulam is considered to be a bad example since it often is not recycled. It is important to increase the common knowledge about the material too and to make sure that the concrete and steel industry is not the only sources that provide information about glulam since the information can be twisted.

The transportation of the glulam beams might be changed in the future. Since it is a light material it is easier to transport over longer distances. Probably there will be an increase of large factories producing short beams and that they are assembling the beams at the site. The other interviewee said that the main influence of the transport distance is the cost. The transport is not a cost issue today. If this would be a problem, it is important to add extra value to the product so it will be bought anyway.

There are some experiments to try to do glulam with species other than spruce. Some experiments are also made to have glulam that is more durable for external and weathered use. Economic and standardised joints are developed. It is also important to understand that different countries have different needs. The desired appearance of the beam is also different in different areas. For example, in Italy the customers want to see the timber, but in the United Kingdom they want to have smaller lamellas.

One aspect of the timber industry is that the people working in it like the material very much and are promoting it. It is very emotional to work with timber for the carpenters and they are proud of working with it. This makes the image of wood positive.

4.2.5.4 Italy and Spain

Some things were also discussed about Italy and Spain with some of the Austrian interviewee. The summary is in table 4.2.6 below:

Table 4.2.6 The situation in Italy and Spain

	Italy	**Spain**
Consumption	Increase of 250 % from 2000 to 2005	Today about 200 000 m^3, increasing
Increase in segment	One and two-family houses	One and two-family houses
Trends	The need slows down	Wooden construction + 50 % from 2005 to 2010
Positive	Competing material	
Negative	People consider it bad in fire Lack of education	

Austria has invested in the glulam market in Italy earlier and is now investing in Spain. The result there has been very good, in Italy the glulam consumption increased by 250 % from 2000 to 2005. The reason for this rise is that the building industry did increase and that glulam took market shares from wooden beams and from other materials. The wooden beams have decreased by 10 % at the same time.

Italy is growing with 1 million m^3 a year with the laminated products. In Austria apartment blocks are increasing. In Italy and Spain it is the one- and two family houses that are increasing. The problem in these countries is also that the architects and the engineers do not know how to use the material. Therefore the investors in Italy have started an information site

on internet where the Italian and the German speaking architects and engineers can get help. The architects are now using this site more and more. Here they also have collaboration with an engineering faculty at a university where the architects can ask questions and people from the university answer them.

In Spain the consumption is about 200 000 m^3 and the rise is not as fast as in Italy, but it is beginning to rise. Both in Spain and Italy, the glulam is mostly used in the country side and in smaller buildings.

Cross laminated timber is growing in Italy and Spain for using in one family houses. This is a young product and it goes well together with the glulam beams. Cross laminated timber is more like concrete and it is better for insulation. This can be used in the southern parts of Italy too. The forecast for the combination of glulam and cross laminated timber is good: "They are like brothers", as one interviewee said.

The trends for wooden constructions here are +50 % from 2000 to 2005, and it is estimated to be +50 % from 2005 to 2010. The reason for the increase seems to be that people want to live in a healthy surrounding. The ecological aspects are important in Italy and Spain.

The fear for using glulam is that people think that it is bad to use in case of fire. The information that this is not the case has to be told and well known. One aspect is also the lack of education for glulam at the universities that leads to the lack of knowledge of how to use the material. It is also important that the consumers wants wooden buildings. This is why marketing activities are important. The consumers can influence the architects and the engineers too if they know that there is an option to choose glulam.

Glulam is considered to be a competing material, especially when the price of steel is growing. Now the steel goes to China. Now the steel and concrete industries are defending their positions since they are energy demanding when the products are produced. This has to be noticed so the transportation issue with glulam is not made a negative part, since the concrete is made more locally. Many of the arguments that are logical to the glulam industry can be turned against the industry from the concrete and steel industry. The glulam industry has to be aware of this. Today the public in these countries like wood, they think it is cosy. It has to be sure that the positive associations with wood will remain.

4.2.5.5 United Kingdom

Steel and concrete are the main competing materials. They say "we don't cut down trees" to give their materials an advantage. The advantage of using concrete is that it is cooler in the summer. The best thing is to work with hybrids to get the best thing out of each material. To do this, the education has to be better.

The durability of glulam compared to other materials is no problem, but the clients think that glulam last less time. It is also important to know that glulam is easy to reuse. The beam is taken down and used in another building. How long it can be reused is not known. The limit of time is dependet on the glue or bonding. Some more knowledge about this would be good. To make glulam last as long as possible, research is needed, good planned maintenance work and good protection where it is needed.

A concrete-framed building has to be knocked down and cannot be reused. The steel-framed building is not so good since the beams have to be remelted to be used again. This demands energy.

Glulam is easy to use and environmentally acceptable to use. A discussion in the UK is if the CO_2 store in the timber can be counted. The reason for it is if it will be used as landfill, then methane will be produced which a much stronger greenhouse gas than carbon dioxide is.

Glulam is best to use inside since no preservatives will be used. If preservatives are needed, today they are much better than earlier considering VOC for example.

The public love timber; they like to touch it since it is soft to touch. This makes it psychologically good to choose timber, but unfortunately they are afraid of the degradation of timber.

The price level of glulam is initially more expensive, but it must not be treated against fire which makes it cheaper in the long run. The glulam-building is also easier to do rooms in. Once again, it is important to show a system and to sell it than just to sell glulam beams. This includes services and also for examples floor and wall connections. It is also important to educate that glulam is a competing material. In the future, the price of glulam will decrease compared to the rival materials.

What is leading a producer to choose a material is mainly what they used the last time, much habit-oriented. The supply-chain is then known and the constructors have a regular basis. There is no benefit of using glulam in this point of view since it is such a small part of the market.

To increase the consumption of glulam, education is very important and so is a system design. The architects do not know where to start to get the information of how to use glulam today. It is also important to educate the architects and engineers at the universities.

London is as close to Europe as to Scotland, which makes the transport of glulam to UK easy. Since glulam uses less energy when it is produced, it should be possible to be transported a longer distance (if the energy consumption is added). The cost of transportation will increase in the future and if glulam then will be cheaper then other materials, it will be an advantage to use.

4.3 THE ENVIRONMENTAL COMPARISON

In this chapter the environmental aspects of glulam compared to reinforced concrete and steel are looked at. First more information about earlier comparisons is shown and the last part is a comparison where only the frame of a building is compared. The original building is glulam-framed, then it is calculated which type of steel and reinforced concrete beams are required for the same use of the building. The environmental comparison is then by multiplying the material needed in each case to the CO_2-equivalents produced when producing the materials.

4.3.1 Earlier comparisons

There are some comparisons between wood and concrete building material where a 4-store compartment building containing 16 apartments with a usable floor area of 1 190 m^3 are studied (Gustavsson & Sathre, 2006). The conclusion made by the authors was that the use of wood instead of concrete could reduce the effective means of reducing fossil fuel use and net CO_2 emission in the air. This is especially if the wood by-products would be better integrated into energy systems. The calculations were based on the material needed for the two buildings based on wood and on reinforced concrete and where the materials required for construction were functionally equivalent. In this comparison, the energy and CO_2 balances of the steel from the reinforced concrete, is recycled steel. The energy demand from this assumption is of

course much lower than if primary steel production from ore were calculated. To compare how much the energy demand differs, Worrell *et al* (1997) compare the energy and coal needed to produce one tonne of hot rolled steel from 100 % recycled steel and from 90 % ore and 10 % scrap. The result was that the recycled scrap required 2.6 GJ coal and 2.9 GJ electricity when the electric arc furnace process[5] were used. The 90 % ore and 10 % recycled scrap required 16.1 GJ coal and 0.7 GJ electricity using the basic oxygen furnace[6]. The study was also investigating which factors that contributed mostly to the energy and CO_2 balances. The result of this was that the recovery of wood-based by-products for use to replace fossil fuel has the most important impact. In this study, the most efficient production methods were assumed to be used. In fact, this is not the case because of spatial and temporal dynamics. The energy balance for the wood-framed buildings was negative in all cases except one. The meaning of this is that energy were released and not consumed in the life cycle.

One example of a comparison made according to the large scale buildings is Gardemoen airport outside Oslo in Norway (Petersen & Solberg, 2002). There the comparison was made for greenhouse gas (GHG) emissions and energy use over the life cycle of glulam and of steel. The total energy consumption in manufacturing steel beams was two or three times higher than in the manufacturing of glulam beams. The use of fossil fuel was 6-12 times higher when manufacturing steel beams compared to the glulam beams. In the most likely scenario steel manufacturing gives five times higher GHG emission compared to the glulam beams. One thing that can either be favourable or unfavourable of glulam is the waste handling of it. This depends on how glulam is used for energy production or being landfilled. Here the analysis pointed out that the glulam construction cannot be more than 1-6 % more expensive than steel at this time. This is because the price per tonne avoided greenhouse gas emission became high compared to the CO_2-tax on gasoline in Norway. If using glulam instead of steel, the avoided tonnes of CO_2-equivalents[7] emitted were 0.24-0.31 per cubic meter. The calculation was made based on the input of sawn wood. In this case the carbon fixation on forest land was not included. If the carbon fixation is included, then the number of avoided tonnes thanks to the use of glulam instead of steel rises to 0.40-0.97 tonne per cubic metre.

An environmental product declaration has been made by IVL, the Swedish Environmental Research Institute (Erlandsson, 2007). In this the calculations of the environmental influences of an average glulam beam that is produced in Sweden for the national and international market is made. When the beam is produced, the influence on the climate is 45 kg CO_2-equivalents per m^3.

4.3.1.1 Different results when the estimation is different

When a calculation is made over how much energy a life-cycle of a material will be, it is important to realise that the production phase is small compared to the time the product is

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[5] Electric arc furnace is a common process to re-melt scrap to reuse it. The advantage is the large reduction of energy per unit weight demanded to produce steel. It is also a flexible system and it is rapidly started and stopped and can easily change the production (The Heat Treat Consortium, www1).

[6] Basic oxygen furnace is the most common method of the steel manufacturers today. To reduce the impurities in the melt ore, pure oxygen is blown through the molten bath. The impurities are then carried to the surface of the bath with help of added burnt lime, burnt dolomite and fluorspar (The Heat Treat Consortium, www2).

[7] CO_2-equivalences are a common figure to make the emissions of different greenhouse gases comparable. The different gases are compared in CO_2-equivalences since CO_2 is the most common greenhouse gas. Greenhouse gases that are important in this case are methane (CH_4) and nitrous oxide (N_2O) which are 25 respectively 298 times stronger than carbon dioxide (IPCC, www).

used. At least this is the case when we are looking at building materials. When different buildings are compared, the life time for them are estimated to be 50-100 years. If you assume that the same energy is used for operating the buildings which is the dominant part of the life cycle, then the concrete-framed building will use 6 % more energy than a wooden-framed counterpart. Similarly a steel framed building would use 14 % more energy than the wooden one (Cole & Kernan, 1996). If just energy aspects are looked at when putting a house together and production is not included, then steel has the lowest energy consumption and wood-framed beams is slightly higher. Concrete's energy demand is significantly higher in the construction work (Cole, 1999). In previous studies there have been suggestions that when building with concrete, it will use more energy than building with wood (Sathre, 2008). Adalberth's (2000) results were that 88 % of the life-cycle energy was consumed in the operation phase for the wooden buildings and 87 % of the life-cycle energy was consumed in that phase for the concrete buildings. This figures were calculated when the life time were estimated to 50 years.

If the land use, the biofuel supply and the end-of-life alternatives are considered when comparing the different building materials then the energy demand are different. When comparing a multi-story building built with wood- or concrete frame, the concrete alternative was about 60-80% higher (Börjesson & Gustavsson, 2000). This comparison was considering the use of forest, processing residues and the use of the demolished wood as an alternative to fossil fuels. The alternative land use was also considered since a harvested forest is replanted and the growing forest will also store carbon. But the effect of an increase of the carbon storage in wood products is small compared to the effect of the reduced fossil carbon emission (Buchanan & Honey, 1994). The most important thing is to reduce CO_2 in the atmosphere and to lower the use of fossil fuel and not to try to reduce it after it is released into the atmosphere.

4.3.1.2 The glue in glulam

Formaldehyde (CH_2O) is one of the most commonly known chemicals. The reason is that after the 70's it was a discussion that the particle board industry's products emitted this gas (Wallin, comm. 2008-05-20). Formaldehyde is by the Swedish Chemicals Agency described as poisonous when breathing, touching and for consumption, but also allergenic and carcinogenic (KemI, www). The threshold values of formaldehyde used in glulam has no problem of being approved. When using the MUF[8]-glue the emission of formaldehyde is less than 0.03 mg/m^3 and the threshold value of the E1-norm is 0.13 mg/m^3. When the PRF[9]-glue is used, and it is used for the Japanese market, the threshold value of the F**** is less than 0.15 mg/dm^3 and the standard is 0.30 mg/dm^3 (Erlandsson, 2007). This amount can be considered to be about the same also in the other producing countries that are included in this thesis work (Serrano comm. 2008-05-22). The reason for this assumption is that the glue used in the Swedish production is the most common one in the world. The fear that the glue in glulam is bad for you is therefore not based on facts. When glulam is burned after demolition of the building, the formaldehyde is not dangerous since the molecule is breaking apart from the heat (Wallin, comm. 2008-05-20). When Erlandsson (2007) did an environmental product declaration it is said that the emissions when glulam is burned is similar to the emissions when plain wood is burned. He also says that glulam is an excellent fuel. The ash from the incineration should be returned to the forest to create a cycle of the nutrients.

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[8] Melamine-Urea-Formaldehyde-glue (Gross and Fröbel, 2007)

[9] Phenol-Resorcinol-Formaldehyde-glue (Gross and Fröbel, 2007)

4.3.2 Comparison of the frames

The comparison between glulam, steel and reinforced concrete can be estimated in the whole building when comparing the function of the building or comparing the actual frame. Here, a comparison is made where just the frames are compared. In a concrete-framed building, the joists can be made from wooden based materials or some other combination. Normally it is common with reinforced concrete-frame and concrete joists or steel frame and concrete joists and glulam frames and wooden joists according to a former design engineer (Segerman, comm. 2008-05-20). One building that will have glulam beams was the starting point. The type of beams that were used here, were compared to the beams of competing materials and the same forces could be carried in the different frames. Also the bending resistance was calculated to be the same for the reinforced concrete and steel frame.

The real building would be 16 m broad and 24 m long. The height would be 15 m to the ridge. In the glulam building in each pillar point it is actually three pillars that are kept together with two boards. This is to stabilise the building more since glulam is a light material and it is not as anchored as heavier material like concrete. This has to be considered when dimensioning the building according to the wind influence.

The calculation for comparing the frame to see the difference for how frames composed of different material would influence the environment, is shown in Appendix 4: The Comparison Construction Calculation. A frame made of glulam was the starting point. How much material that was used here was then calculated. Which type of steel and reinforced concrete that were needed were calculated by a constructor named Sarah Segerman. The material required for both steel frame and reinforced concrete structures were then calculated. The volume materials needed in the three cases were then multiplied with the CO_2-equivaltens needed to produce the materials. To get the CO_2-equivalents, different sources were used to get reliable numbers.

For the CO_2-equivalents for glulam, a declaration of content from Moelven Töreboda that were made by Martin Erlandsson at IVL Swedish Environmental Research Institute was used. The result was that the climate influence from the production of glulam was 45 kg CO_2-equivalents per m^3 (Erlandsson, 2007).

For concrete, the newest information came from Jeanette Sjunesson and the department of Technology and Society, Environmental and Energy Systems Studies at Lund University in Sweden. The work is called Life Cycle Assessment of Concrete and was published in 2005. There the results were that 225 kg CO_2-equivalents/m^3 was needed when producing ordinary concrete and 340 kg CO_2-equivalents/m^3 was needed when producing frost-resistant concrete (Sjunesson, 2005).

Steel is not only used for the steel beams, but also for the reinforcement of concrete. From the European Commission the values for steel rebar is 1.00188 $C0_2$/kg, 0.00058 CH_4/kg and $4.07*10^{-5}$ N_20/kg (European Commission, www). Comparing other steel types gives about the same results from the European Commission. To get these figures into CO_2-equivalents, CH_4 is a 25 times stronger greenhouse gas, N_20 is a 298 times stronger greenhouse gas (IPCC 2007). The CO_2-equivalents for steel rebar is as follows:

1.00188 CO_2/kg steel rebar +

0.00058 CH_4/kg steel rebar * 25+

$4.07*10^{-5}$ N_20/kg steel rebar * 298 =

(1.00188 + 0.0145 + 0.0121286) CO_2-equivalents/kg steel rebar =

1.0285086 CO_2-equivalents/kg steel rebar ≈1.0285 CO_2-equivalents/kg steel rebar =

1028.5 CO_2-equivalents/tonne steel rebar

The total influence of the same building if the frame is glulam, steel or reinforced concrete is as shown in Table 4.3.2 below. There the different alternatives are shown also according to which type of concrete that is used.

Table 4.3.2. The results from the comparison of the environmental influence of the different materials a type of building can be built with.

	Volume used in the building (m^3) *Alternative: tonne (material)*	kg CO_2-equivalents/m^3 *Alternative: kg CO_2-equivalents/tonne*	kg $C0_2$-equivalents for the different reinforced concrete options	Total kg CO_2-equivalents for producing the frames
Glulam	134.2 m^3	45		**6 032**
Reinforced concrete	Concrete: 138 m^3	Ordinary: 225 Frost-resistant: 340	31 050 46 920	**39 689.4** **55 559.4**
	Steel: 8.4 tonne	*1028.5*	8 639.4	
Steel	*54.4 tonne*	*1028.5*	8 639.4	**55 950.4**

Frost-resistant concrete is not used in this type of buildings, therefore 39 689 CO_2-equivalents are the most trustable answer (Segerman, comm.. 2008-05-20). The CO_2-equivalents required when producing steel frames and reinforcement are most likely not the same (ibid). More information about this has not been possible to reach; therefore the same figure is used.

5 DISCUSSION

In this part the frame of reference and the results are discussed for a deeper understanding of the glulam market in Europe.

5.1 To obtain an understanding of how glulam is used today and the forecast for the future.

The competitor oriented objectives are important in the view of the glulam producers towards other material. To increase the use of glulam, the producers have to see the competitive materials as the rivals and not other glulam producers. If the competition is between the glulam producers, then the risk increases that the consequence is the experience curve strategy that will lead to the reduction of prices faster than the competitors in your own market (Lieberman, 1987). Since the building industry in other parts of the world is declining, more of the glulam produced in Europe must be consumed locally. This is of course influenced by the crisis in USA. Even if the building will start again in the US, there are other aspects that can lead to the same result. For example the same problem is occurring with increasing taxes on transports. This makes it more expensive to transport the material to other continents and more of the glulam have to be bought here. To increase the use in Europe, the strategy should not be competitor oriented according to Armstrong and Green (2006). This is one aspect that some of the interviewee also said, that it is important to have a united front towards the steel and concrete industries. The use of glulam is still minor compared to its competing materials, and therefore the glulam industry should cooperate to increase the use of it. The important thing is to increase the use of glulam compared to other materials. To show how glulam can be used, it is not only important to show some buildings with glulam beams, it is just as important to show the technical solutions when building it. For this, the glulam producers do need the technical knowledge when selling the product. The architects and the constructors will ask for this knowledge, as several of the interviewed persons said. There should then be cooperation between the different glulam producers to help to provide this knowledge to the potential customers. The focus should therefore be on competing with other materials than to compete with other glulam producers. The success measuring should therefore not be on market shares within the glulam industry, but to compare the outcome with the market shares with other construction materials. The theory discussed by Armstrong and Green (2006) is in accordance with what some of the interviewee said. The main thing should be to sell glulam and not to talk about the differences of the glulam beams from different producers. This aspect of the market differs from the producers who mainly produce standard beams and those who produce special beams like curved one. The standard beams producers have less technical knowledge about building with beams. The producers that use and sell different beams to different products have of course more knowledge about the technical aspects. As one of these said, we need support from the whole chain to be able to show the technical solutions when building with glulam since the architects and builders know so little about the material. As said in the interviews; it is not enough to just show how a building that has been build with glulam beams looks like. It is very important to sell the "solutions", to show how you can do it. When an architect or a builder sees a glulam building, he or she wants to know how it actually was made. There are too few people that know this.

In the interview it was also pointed out that compared to other materials, the glulam producers have to have their own engineers to know and to show how the material should be calculated and build with. This means that the knowledge has to be where the producers are, so that also the producers know how and where glulam is used. A wish from glulam producers was to

make a system for how to use and calculate, it would help the user with the whole solution. This demands also for example for efficient software for glulam. Today different programs are needed for calculations when using glulam.

In those countries that are not used to build with wood, the knowledge has to increase from about nothing to a platform of knowing the technical opportunities of using the material. An illustration of the knowledge problem can be shown like a stair. The first step is knowledge that glulam is an option when choosing material for the frames. The second step is knowledge about the technical aspects of glulam; how to calculate for the building, the fire-resistance, the light weight, easy to work with, demands a dry site when constructing the building etc. The third step is the environmentally acceptable aspects. Glulam should be chosen when it is a good solution using it, knowledge has to increase about all these three steps.

By the results from some of the interviewees it can be interpreted that environmental aspects are the best argument for selling glulam. Glulam is the most environmentally acceptable building material to use in many different buildings, but only when the technical solution is right. If the solution for glulam is not as good as another alternative, then glulam should not be chosen. In many cases there is an advantage to use glulam in a specific area. The advantage could be that it is more price efficient, less time demanding, better technical solution or that it is chosen since it is more environmentally acceptable. The last mentioned case is often when a building could be chosen to be build with different types of beams, then the environmental aspects can influence the results. Most important to have in mind is that the right material should be used in the right place. Of course it is important to realise that glulam can be used instead of other materials and that there are several advantages of it, here the knowledge has to increase.

Among glulam producers knowledge about the product differs. Some of them sell the product, others sell the solution. The lack of knowledge of glulam within the potential market demands more work from the producers for informing about the product. As said in chapter 3.1.3 knowledge management is a key factor for corporate entrepreneurship and growth success (Guadamillas *et al,* 2008). To sell glulam, the whole solution has to be shown, especially when not building ordinary buildings. New knowledge is best used together with old (Galunic & Rodan, 1998) and this is the same case for glulam. The builders that are usually using concrete and steel should get information on how to use glulam. Then they will use it when the conditions for it are positive. There is a potential to increase the use of glulam, among other things since the interest in environmentally acceptable products are increasing. To increase the market share compared to other materials, the knowledge about glulam and how to use it has to increase. The experience of using glulam in different buildings and surroundings are getting larger when it is used more. To show these good examples and learn from each others experiences is a good solution to increase the competitive tools against other materials. The companies that are actually working with the whole solution when building are the one that compete with concrete and steel, therefore they should be supported by the wood industry. It is here the competition is as was said in the interviews.

If a constructor or architect chooses glulam frames, the glulam companies often have to provide the builders with help with for example calculations. As Itami and Numagami (1992) wrote the firm seeks to find resources needed for growth. This is the case when the glulam producers have realised that they need to offer the engineering knowledge to their costumers. The competitive advantage is the providence of knowledge and this should not be neglected by the management. To lose this is to lose the capability of competing with other materials. This is the basic knowledge that is very important for especially architects to know, they are often the one that choose the material to build with. The glue in glulam is an issue where

more information has to be provided. The scepticism towards this can only be met by information.

The resource based view is based on focus of the special resources a company has. Here glulam producers can be compared since some of them sell the whole solution, others sell the product. These different products have dissimilar resources and do not act the same way. All knowledge in the company has to be used to optimise the conditions for a company. According to Barney (1991) and Hoskiron *et al* (1999) this is the right way for synergy effects. The different types of companies are focusing on engineered products with help for the constructors or straight beams with no help, according to the interview.

It is important to do it the right way, so the products are not sold to someone who does not know how to handle it. If you do not sell the product and do not know how it is used, there is a risk it is used incorrectly and then no one wants to use it. The producers/constructers have to know what is needed for using glulam.

It is also important to use the material effectively and combine the material with other material when this is the best solution. The reason for using glulam should be because it is the best thing to use in this particular object and in this particular part, so it is important with the knowledge that glulam exist and what the advantages of using it are.

You have to sell the engineered product, show its advantages. People do not chose a material just because it is environmentally acceptable, this can be a good side effect, but it is not the reason for it.

The glulam producers have to work together within the country and within Europe. The competitors are steel and concrete, not other glulam producers. The whole sector has to cooperate to show that glulam is a very good material to work and to build with. It is not gaining the glulam market by saying that the glulam that is produced in Finland or in Austria is the best one compared to the other; this is much for the users to know. Now it is like this according to some of the interviewees, and it is mostly because the forest owners want to increase the selling price from their area, and they have paid for the advertisements.

It is discussed if legislation can lead to improvement in corporate environmental attitude, and profit and environmental responsibility has been positive according to some sources, negative according to others or no relationship as mentioned in chapter 3.1.4. In the interviews it is said that in some countries the legislative trends will have a positive impact on the use of glulam.

The interviews pointed out an interest for environmentally acceptable houses amongst more educated and higher income groups. This group is not as traditional as others and they trust new research and can pay for it. The unique stakeholders that influence the builders there are affecting them. Here the end users influence the material choice. In other cases glulam is chosen for the environmentally acceptable aspects, mostly when the end-user are deciding. For example in municipal buildings when a mayor wants to show an environmental friendly side or a company is doing the same thing. This was said both in France and in the UK. The results from the interviews said that mainly the architects decided which material could be used. Here glulam is chosen for its technical aspects. The knowledge about this has to increase since the architects are influencing the choice of material and the usage of it.

Although the glulam producers that were interviewed realises that glulam is sold on the technical solutions, the environmentally acceptable aspects are a positive fact that should not be forgotten, especially when this is influencing the end-users. Hoffman (2002) is discussing climate change in terms of Business strategy. The example in his paper about the energy demanding site can also be the case for an energy demanding production and construction

site. Why chose a house that demanded much more CO_2 when it was constructed if you can choose something else?

Glulam is an available material with a positive feeling and today people that worry about the environmental aspects build timber framed houses. Glulam is easy to machine and easy to work with at the construction site. This was the case in Germany according to the interviews. In UK where the environmental discussions are very intense, glulam is used in buildings that are designed with environmental structure. About the future, it is considered to be positive if the knowledge about the material rises. Probably more production sites will start, especially in former Eastern Europe. Probably more large buildings with glulam frame will increase. If environmental aspects will influence the use of glulam it is because it is less energy demanding. In UK the future for glulam is considered to be very positive since the government is calculating CO_2-emissions.

5.2 To fill the void regarding the lack of data about the glulam production, consumption and export during the latest years in Europe

The market of glulam in Europe is amongst others influenced by construction, export and the use of glulam in the buildings. As shown in Appendix 2. Construction in some European countries, the population within the countries mentioned will slightly decrease or increase. A residential construction is the largest part for all countries. Czech Republic, Poland and Slovak Republic are the countries where the increase in residential buildings will increase most. The other countries expect a decrease. It is no news that the population in Europe is getting older. This influences which type of buildings that are needed in the future. This is one of the reasons that residential buildings do not increase in most of the countries except in the former Eastern Europe.

Comparing the countries in the text, in Czech Republic, Hungary, Poland, and Slovak Republic buildings that are not residential is a larger part of the total building sum. Important to notice is the difference in volume million Euro between the countries. For example residential construction in Czech Republic is forecasted to 3 500 volume mill. Euro in 2010, in France the figure is 45 000. Industrial and office buildings have a larger volume million Euro each in France than residential buildings in Czech Republic. As can be seen in the appendix, volume million Euro for different constructions and the population in a country does not have a direct connection. For example Belgium and Czech Republic have almost the same amount of inhabitants but construction is about twice as large in Belgium as in the Czech Republic. The population in these two countries is similar.

The countries where residential buildings are the biggest part compared to the other groups are Denmark, France, Germany, Ireland, The Netherlands, Portugal, Spain, Sweden and Switzerland. There is some more detailed information about France, Germany and Spain from 1995 to 2006. In France it can be seen that buildings for agricultural purposes are around 12 to 13 million m^2 during almost all this period. Office buildings have increased to about 3 million m^2 in 2006. Commercial buildings have increased in total to 5 million m^2 in 2006. Storage buildings, non-agricultural and buildings for agricultural purposes have the largest square metres, residential buildings are not in the figure. In Germany it says that private housing starts are the largest sector, multiple units are second and commercial buildings are third. All groups have decreased in figures from 1995 to 2006. The figures for 2005 are estimated and for 2006 the figures are forecasted. In Spain it is shown that residential housing starts are in a clear majority to non-residential housing starts. Here a clear increase for the total figures has taken place from 1995 to 2006.

When distinguishing between wooden frame buildings and concrete or steel framed structures, it is important to know that in a wooden frame building wood is often not the only sole material used and a concrete building has also wood in it. Often in a wooden house the foundation is in concrete. In a house built in reinforced concrete, wood is used in roof-framing, doors and windows etc. Also wooden framed buildings may need a lot of plasterboard to cover the wooden framing.

Different markets need to be seen as just different markets. It is no good to try to enter a new market just the same way that you entered the others. There is a difference compared with countries that traditionally build with timber and other countries. If you want to enter a market that traditionally use stone and concrete as building material, then the first thing to focus on is the technical advantages as glulam is a light material compared with how much weight it can carry and has also good fire resistance. It is important to show that the material is a good alternative to concrete and steel beams, since this knowledge is poor especially in the traditionally stone building countries. The lack of knowledge can be shown in statements like; can timber really carry the weight of a roof? After showing this, then other aspects can be informed about. For example in France, people want to have a strong house that will last for at least two generations. This country has some of the biggest concrete building firms in the world. This can be seen as a proof of the popularity of building in concrete.

In France, some of the concrete builders have bought some glulam producers. This gives the concrete firm the opportunity to choose glulam for example for the roof if they want to. It also makes sure that glulam is not a competing material when choosing which material should be used, since the concrete company has the power over the glulam producer. When glulam is used is dependent upon the demands of the concrete company. This makes it difficult for the glulam companies to increase the market shares and to compete with the concrete companies.

In the majority of Europe, glulam is considered to be one type of timber beam, the public do not know the difference between glulam and other timber beams. Timber is associated with the material that you burn in your fireplace, so it is associated with a nice feeling. Wood has also a nice feeling when it is touched; it is not cold as concrete and it has a softer feeling.

In Austria commercial buildings are the second largest building group followed by office buildings and then industrial buildings. All of these groups have been increasing and are forecasted to do so until 2010. In a majority of the investigated countries these three groups are the largest one after residential constructions. Miscellaneous buildings may also be one of them.

According to the interviews the market share of glulam was about 10 % in Austria, 5 % in France, 2 % in the United Kingdom and 14 % in Germany, in Germany all wood constructions were included. They all thought that knowledge and education was missing regarding glulam. In the future there would be an increase of the use of glulam products if knowledge and education were increased together with other materials. Also the fact that the price of other materials rises, is an advantage for glulam.

5.2.1 The export of glulam

Although the data for the export is not absolutely reliable since the toll number for glulam also can include other similar goods, the numbers provided can be seen as a hint of the flow from the producing country.

The large amount of glulam exported to Italy from Austria is not a surprise, since it is commonly known within the glulam industry that Austria has promoted glulam there. Until 2006 Germany was also exporting an increasing amount of glulam to Italy. For Norway the export to Italy has decreased, but it is still the largest market. Japan has been the largest

export market for Finland and Sweden. For Austria the export to Japan has been the second largest market. For France, Spain is the largest export market.

From the interview it could be understood that a majority of the glulam producers were sawmill companies. They were not considered to have the technical knowledge needed for using glulam; they had the production for being one step closer to the end-use. Their knowledge about the requirement of the consumer market was missing, according to some of the interviewees. The result of this was that the companies that did help their customers with technical solutions had more to do. On the other hand can glulam be used both as an engineered product but also as straight frames that is not so advanced. For using glulam in the easiest way, more information about the material is needed for the users. Then it is used the correct way.

5.2.2 The market

The use of glulam in a country can be calculated by adding the use of the country's own production and the import. As seen in figure 4.1.3 the largest recipient markets are Germany, followed by Italy and then Japan. Scandinavia and others have increased usage compared to 1999 and are now number four and five, before Austria and Switzerland which had these places in 1999. In 1999 Germany used almost 2/3 of the amount produced in Europe; in 2006 they used 37%. When comparing figure 4.1.1 and 4.1.3, it is shown that more glulam is produced in Europe than is consumed. Therefore the glulam producers have to export their goods to other markets or the use in Europe has to increase. This is important for the price fixing in Europe, if there are more goods that consumed, the price decreases. This is not anything that the glulam producers desire.

As shown in Figure 4.1.2, Germany has been the largest glulam producing country for several years, only Austria has managed to have the same production amount. Finland is now third, followed by Italy, Sweden, Denmark and France. Since the use in Germany was about 1 million m^3 and only about 230 000 m^3 are used in Austria, Austria should export a much larger amount. Here the export figues from Svandata can be evaluated, since the toll number also includes other types of glued wood besides glulam. According to the numbers from Svandata (2008) regarding the export of glulam, it is understood that the export and the use in the countries does not show an excess compared to the production in the country (the export is in tonne, but 1 m^3 glulam weight about half a tonne). This indicates that the export numbers can be used as a guideline, that it is not wrong. It is not said that it is accurate either.

Global competitiveness will promote the transfer of technology to the developing world. In this case, glulam should be used when building in this part of the world too. The knowledge about how to use it should also be provided here. There is scepticism to sell knowledge of how to use glulam to the developing world since they could start producing it and then the export from Europe would decrease.

5.3 To compare the rival materials of glulam with an environmental focus. The rival materials that are focused upon in this thesis are concrete and steel beams. The storehouse sector is a good segment to compare the materials.

The environmental comparison in this thesis work has shown that the environmental influence that a building with the same use but built with different materials of the frames, differs. Glulam is the most environmentally acceptable material to use. The same conclusion was made in the calculations in this thesis work, and in other comparisons. Just the production phase was considered here, but when the whole life-cycle is considered, glulam frame is the most environmentally acceptable alternative.

Some of the interviewees said that there was scepticism towards the glue in glulam. The threshold value is 0.13 mg/m^3 and in glulam the value is 0.03 mg/m^3. There is no reason for suspicion towards glue.

To get more valid results from the interview part, more people could have been interviewed. Especially more architects, since they are the one that choose the material.

A suggestion for further learning or for other master thesis work is to go further into the export data and to see how much of it that is not glulam. As said in the text, it is known that straight-glued joints that are exported use the same toll number. Since the glulam production in Europe is influenced by the use in other parts of the world, it would also be interesting to map out the use and production outside Europe.

6 CONCLUSIONS

As written in Chapter 1, the use of glulam has increased in Europe, so has the production. The use has the potential to increase; most important is to show how to use it. The market today can increase if the knowledge of the technical aspects will increase. For managing to do this, the glulam producers have to work together. The competing materials are steel and concrete, not other glulam producers.

As shown in this thesis work, the reason for choosing glulam is not first of all that it is environmentally acceptable. The technical aspects have the greatest influence and that the material has a good solution for the specific needs. The increase of glulam was illustrated by a stair. Step one is the knowledge that glulam exist as an alternative to other materials. Step two is the technical aspects of glulam, the solutions how to use it. Step three is the environmentally acceptable aspects and others that make the use of glulam more comfortable. This includes its appearance, the warm feeling when touching it etc.

Germany is today considered to be the largest glulam consuming country in Europe. Here and in other places, more advanced buildings with glulam frame are forecasted to increase. In this segment, the technical advantages of glulam is used, this is a positive thing to increase. The common knowledge of glulam is an important thing to increase, so the architects and others know that glulam is an alternative. The question is if the increased use will be with straight beams or more engineered products. The answer is both. Different producers are focused on different types. Both of them have an advantage of an increase of knowledge of glulam.

Austria and Germany are the largest glulam producing countries, followed by Scandinavia and Italy. When comparing figure 4.1.1 and 4.1.3, it is shown that more glulam is produced in Europe than is consumed. Therefore the glulam producers have to export their goods to other markets or the use in Europe has to increase. This is important for the price-fixing in Europe.

According to the interviewees the market share of glulam in Austria is 10 %, 5 % in France, 14 % for wood constructions in Germany and 2 % in the UK. To get an increase of the market share, they all said that the knowledge has to increase about glulam. This includes the product awareness and how to use it. The tradition to build with concrete makes it difficult to get the architects and constructors to choose glulam. It should be used when there is an advantage to use it; price, technical aspects, less time-demanding or environmentally acceptable. Of course the existence of the solution has to be shown and also how to use it, and it should also be chosen for having advantages compared to other materials. Hybrids together with other materials is also something that were discussed, to use the advantage of steel and other sorts of laminated timber, the interviewees were not afraid of cooperation with other industries and materials.

The advantage for glulam in the future is the price rise of steel and the environmental focus. It is important to realise that glulam is not chosen just because it is environmentally acceptable the technical solution is also a key attribute. Much of the results from the interviews pointed out that the problem was very similar in the countries, that there is a lack of knowledge about glulam and that prejudice are common and makes it difficult to increase the use of glulam.

The environmental advantage of using glulam in the frames is showed in this thesis work. The comparison showed that the difference was huge. Glulam used just 15 % respectively 11 % CO_2-equivalents compared to reinforced concrete and steel.

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APPENDIX 1- THE QUESTIONS

The potential

The results of the potential questions will be to see which segments there are of glulam, how big these segments are and how the response is towards this material from the one working with it. Why is the material worked with and why not? Some of these questions are slightly close to the same later on in the questionnaire; the reason for this is to see if the response is the same or if it differs when it is asked in a different way. The common analysis should give the result of which potential glulam has. The questions are:

1. What are the different segments of glulam beams/ different use?
2. How big share of the buildings that could be using glulam is using it today? According to the different segments?
3. What are the advantages and disadvantages of using glulam?
4. The architects, what do they think about the material?
5. The construction workers and the construction leader, what do they think about the material?
6. What is the potential of glulam in the future?

Use of glulam

This group of questions is giving the results how much glulam that is used today and if they are producing as much as they can or if the market does not buy everything that is produced. Also an overview of the market today and how much is consumed is considered to be a good question. The questions are:

7. What do you think will be the ordinary strength class, GL 24, GL 28?
8. The largest glulam producers in Europe, who are they? (Countries and companies)
9. How much do they produce?
10. What is their capacity?
11. How big was the production during the latest 10 years? (Countries and companies)
12. Where did they sell it?
13. Which markets are the largest today?

The forecast

This part is giving an answer to what the respondent think about the future. This includes which markets that are considered to be the large one, the largest producing countries and how big the different segments will have. The reason for these questions is also to see how the answers can differ according to who you are asking. The questions are:

14. Which markets will be the largest one in the future?

15. How will the market shares be in the future?

16. How big amounts will the different segments have in the future?

17. Will the use increase in the future?

The glulam market

This part is giving the answer of the questions based on the theories used in this market analysis. The reason for it is to give a general view to define the market. This is according to the SWOT- and PESTEL-analysis that was described in section 3. The questions are:

18. What are the strengths of glulam?

19. The weaknesses?

20. The opportunities?

21. The threats?

22. The Legislative trends? (increase or decrease the use)

23. The Political trends? (increase or decrease the use)

24. The Economic trends? (increase or decrease the use)

25. The Social trends? (increase or decrease the use)

26. The Technological trends? (increase or decrease the use)

27. The Environmental trends? (increase or decrease the use)

Comparison:

The questions here are for comparing glulam with rival materials. The answers will hopefully be clear according to what are the most important things to be made for increasing the use of glulam. Here we can see the rival materials and their advantages. The questions are:

28. Which are the competing materials in the different segments?

29. What are the advantages and disadvantages of using these competing materials?

30. The durability of the competing materials and glulam?

31. How long time can glulam and the other material "last" (according to humidity, NaCl, cold…)

32. What are included in this time (changing parts, preventing measure…)

33. How to make the materials last longer?

34. How easy are the different materials to use?

35. What are the environmental influences of producing the different materials?

36. What are the environmental influences of preventing degradation?

37. What does "ordinary people" think about the different materials?

38. What are the prices of the different materials? How has it been the latest years and how will it be in the future?

39. Is glulam considered to be a competing material or is it considered to be an alternative just because it is environmentally acceptable?

40. Why is a producer choosing one type of beam, what is the reason for the decision?

41. What would be the most important thing to do to increase the consumption of glulam?

42. Do you think the transportation will change because of the environmental thinking (the distance, the type)?

43. Is there something else that has not been discussed in this questionnaire?

APPENDIX 2. CONSTRUCTION IN SOME EUROPEAN COUNTRIES

Austria's population is about 8.3 million and will increase to about 8.4 million to 2010.

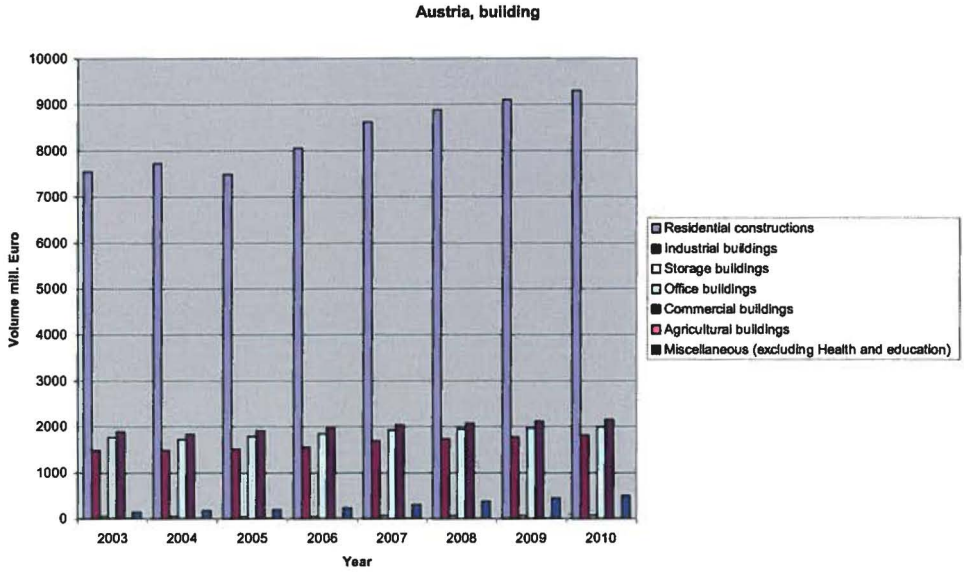

Figure A2.1 Building in Austria in volume million Euro (Czerny & Weingärtler, 2007).

Belgium's population is 10.5 million, and will increase to 10.6 million to 2010.

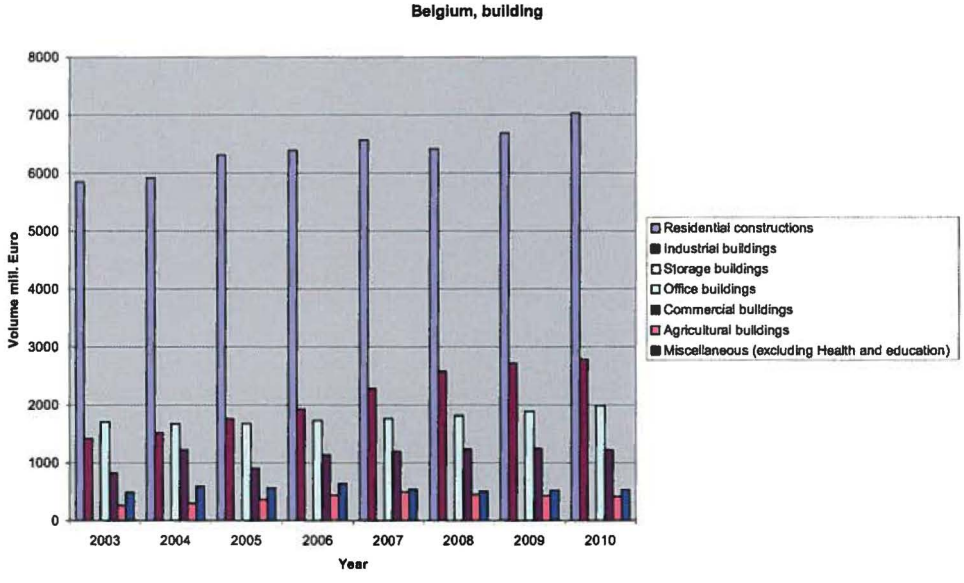

Figure A2.2 Building in Belgium in volume million Euro (Czerny & Weingärtler, 2007).

Czech Republic's population is 10.2 million, and will increase to 10.3 to 2010.

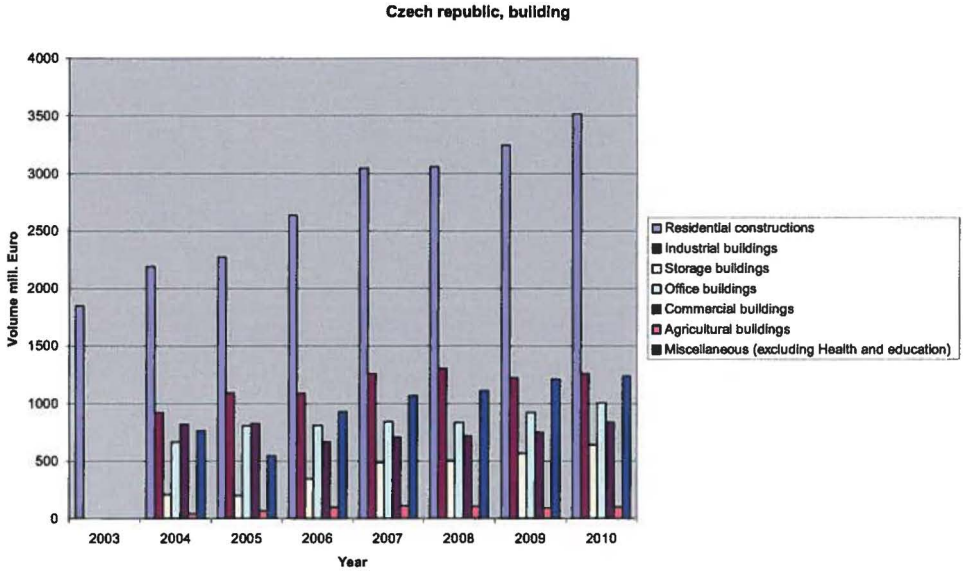

Figure A2.3 Building in Czech Republic in volume million Euro (Czerny & Weingärtler, 2007).

Denmark's population is almost 5.5 million and will be 5.5 in 2010.

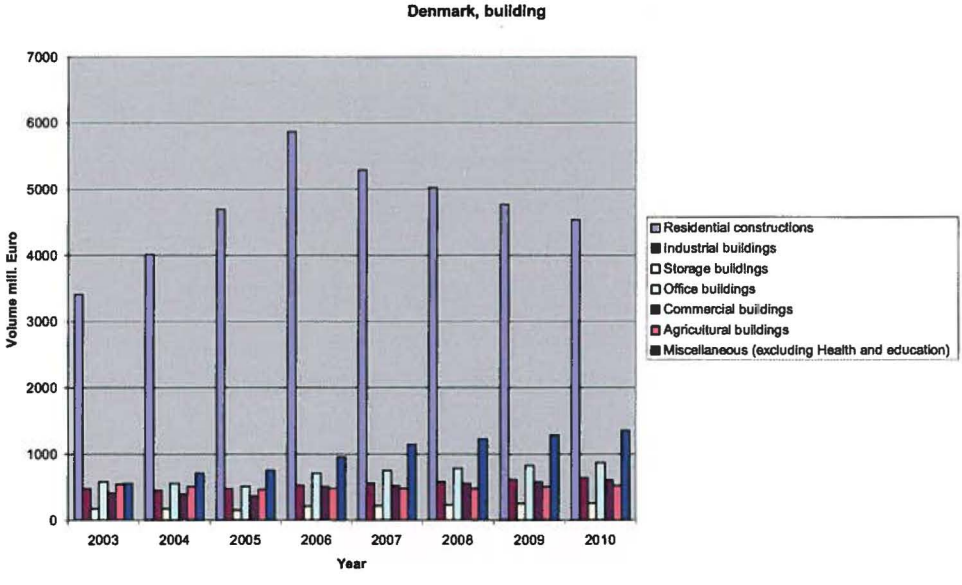

Figure A2.4 Building in Denmark in volume million Euro (Czerny & Weingärtler, 2007).

Finlands population is 5.2 million and is forecasted to be almost 5.4 million in 2010.

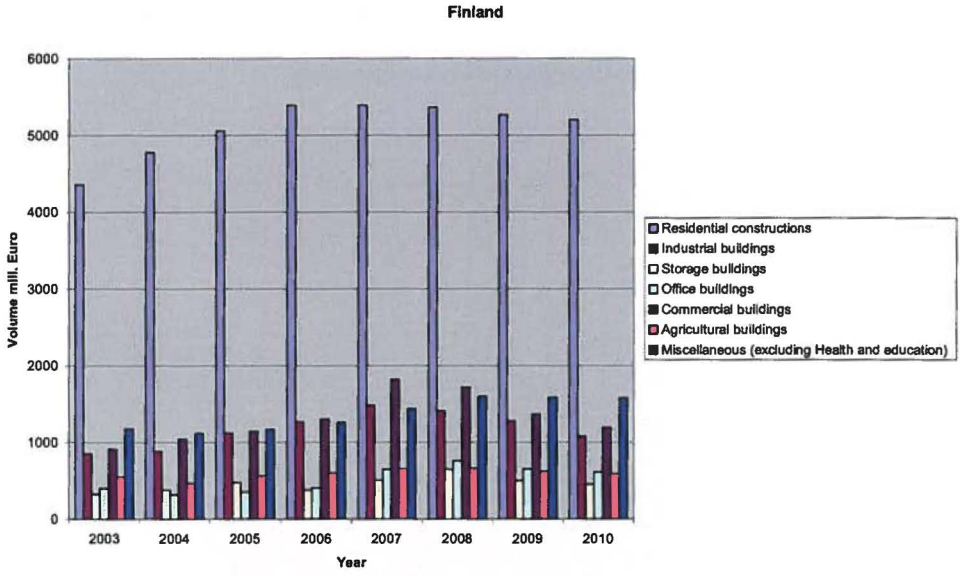

Figure A2.5 Building in Finland in volume million Euro (Czerny & Weingärtler, 2007).

France's population is estimated to be 61.9 million and will be almost 62.6 million in 2010.

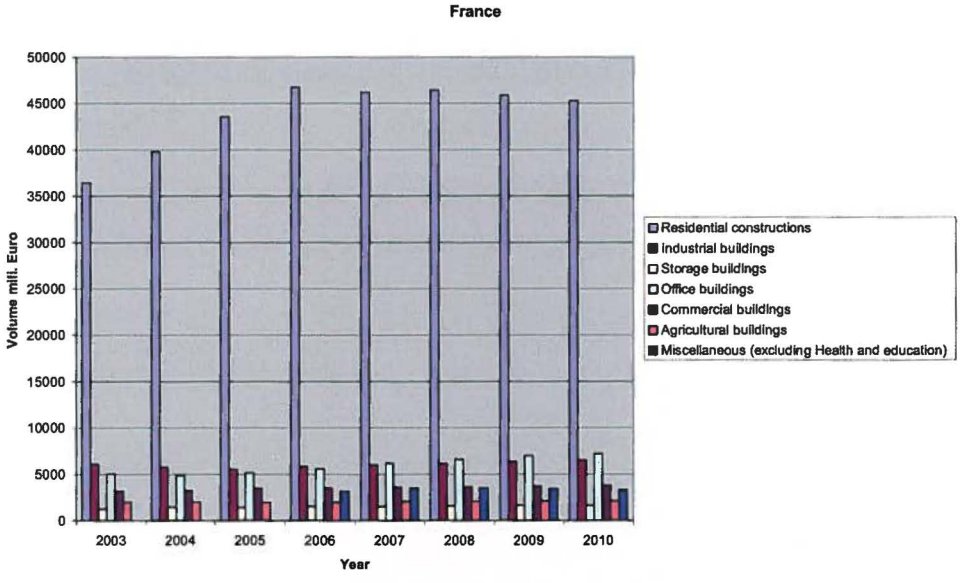

Figure A2.6 Building in France in volume million Euro (Czerny & Weingärtler, 2007).

In France the housing starts in 2006 was the best year in more than 25 years with the number of 421,000. New production for non-residential buildings rose by 8.5 % in volume. This rise was after an increase of 9.4 % also in 2005. The area of new buildings has been as follows:

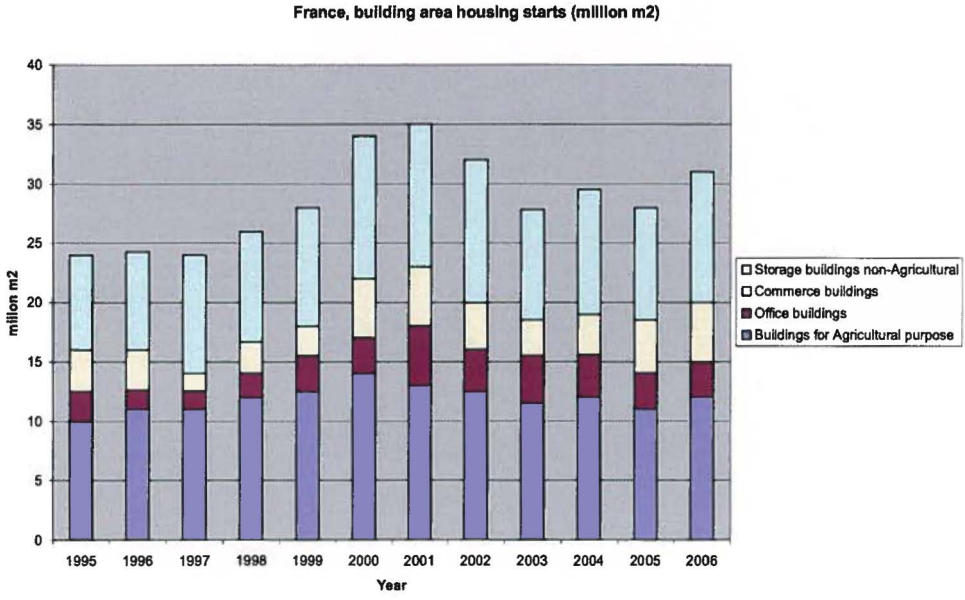

Figure A2.7 The building area in million m^2 for the housing starts in France (Instituto Nacional de Estadística, www).

Germany's population is 82.3 million and is estimated to decrease to 82.2 million to 2010.

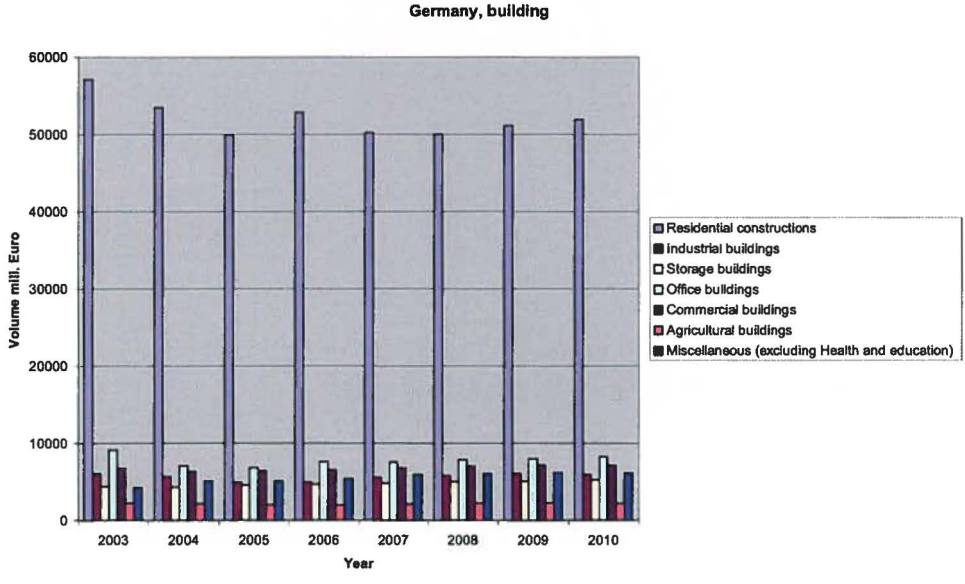

Figure A2.8 Building in Germany in volume million Euro (Czerny & Weingärtler, 2007).

Number of housing starts in Germany is as follows:

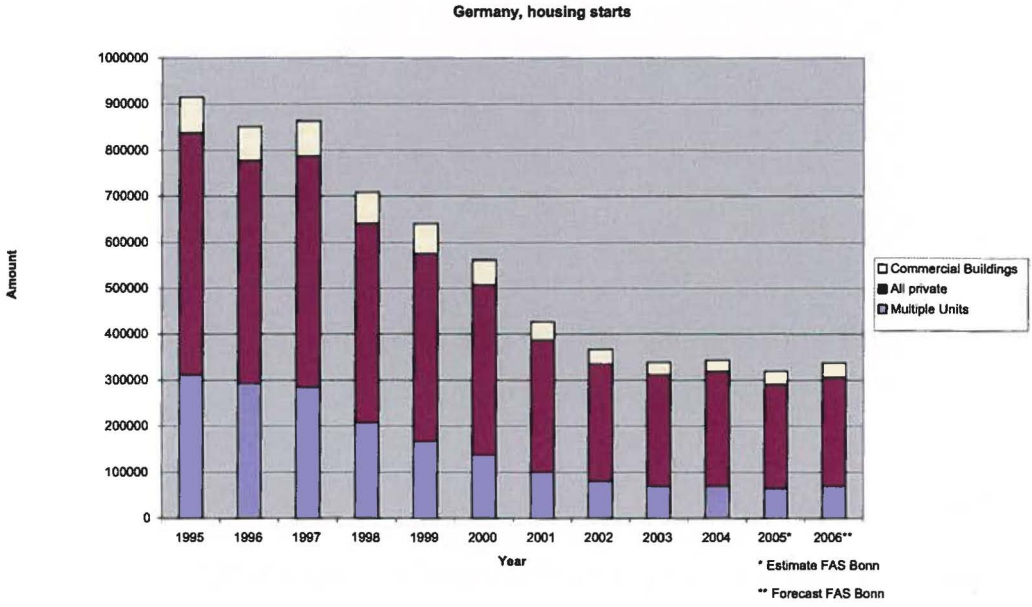

Figure A2.9 The amount of housing starts in Germany from 1995 to 2006 (Federal Statistics Office and for year 2005 and 2006 FAS Bonn, 2007).

Hungary's population is just above 10 million, and is estimated to decrease to 10 million to 2010.

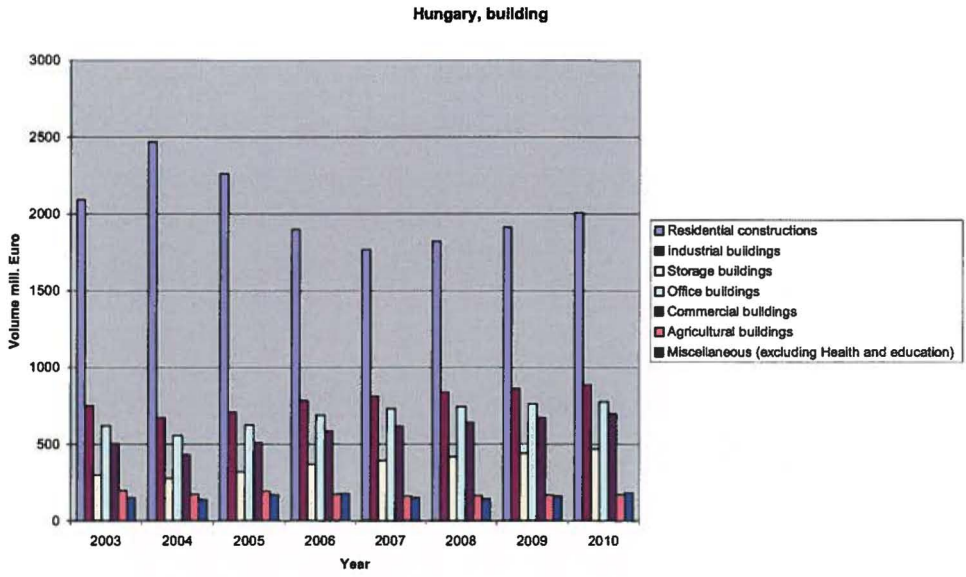

Figure A2.10 Building in Hungary in volume million Euro (Czerny & Weingärtler, 2007).

Ireland's population is 4.4 million and is forecasted to be 4.6 million in 2010.

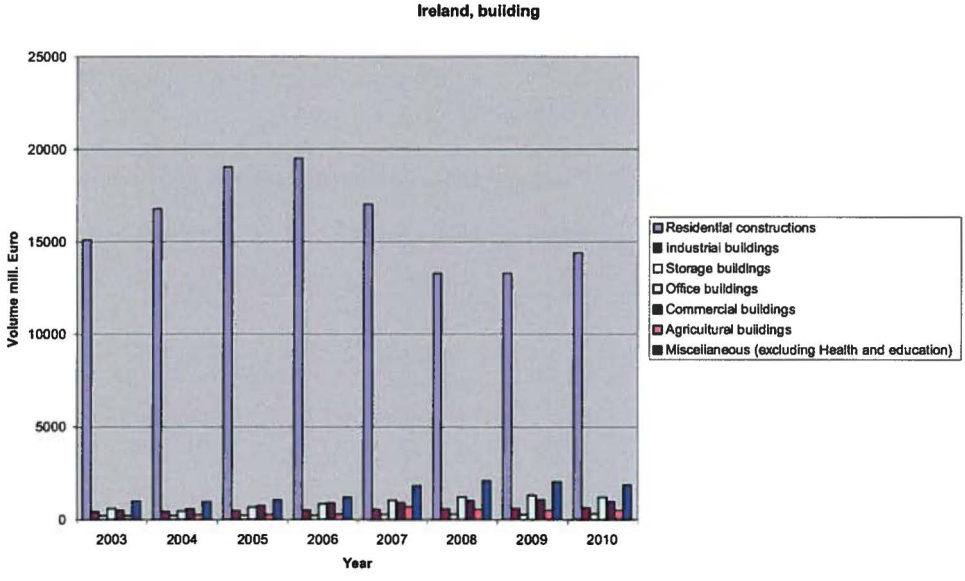

Figure A2.11 Building in Ireland in volume million Euro (Czerny & Weingärtler, 2007).

Italy's population is 59.4 million and the outlook is that it will increase to almost 59.8 million to 2010.

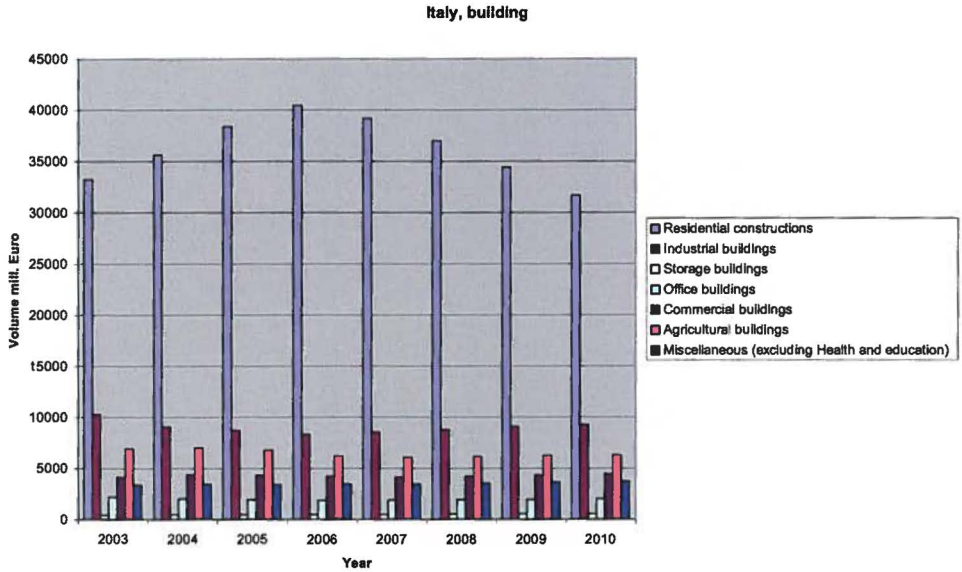

Figure A2.12 Building in Italy in volume million Euro (Czerny & Weingärtler, 2007).

The population of the Netherlands is 16.4 million and the outlook is that it will be 16.5 million in 2010.

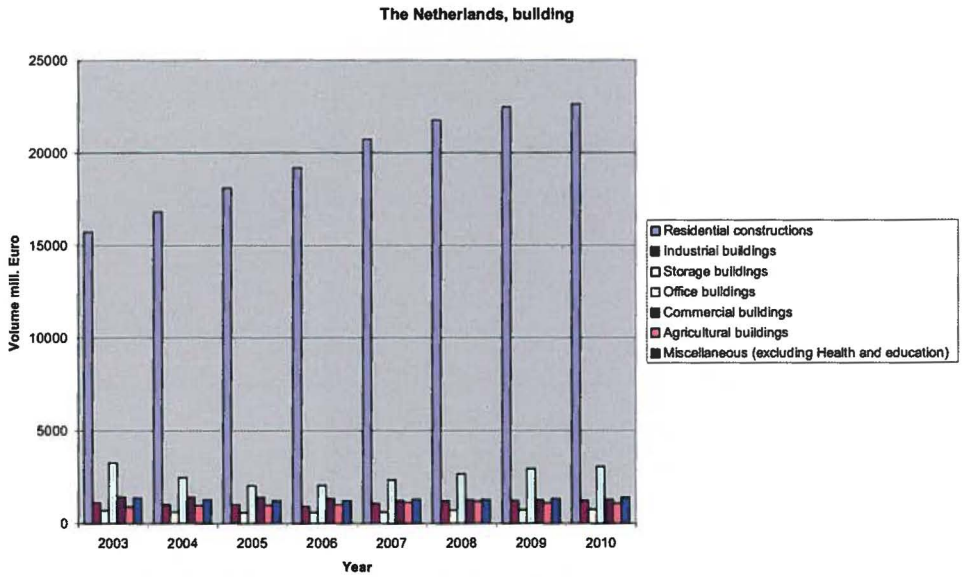

Figure A2.13 Building in the Netherlands in volume million Euro (Czerny & Weingärtler, 2007).

The population in Norway is 4.7 million and is forecasted to be 4.8 million in 2010.

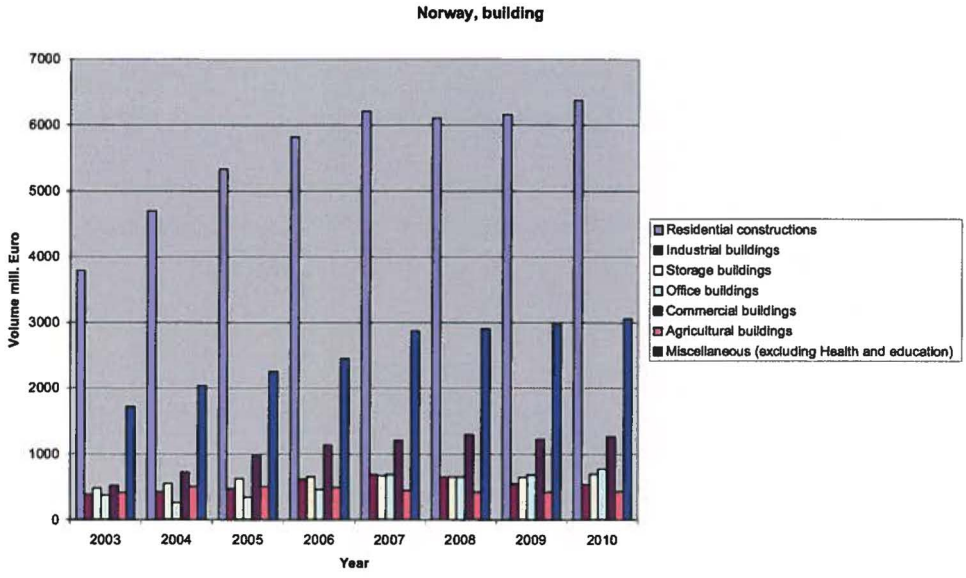

Figure A2.14 Building in Norway in volume million Euro (Czerny & Weingärtler, 2007).

Poland's population is just above 38 million and it will decrease to 38 million to 2010.

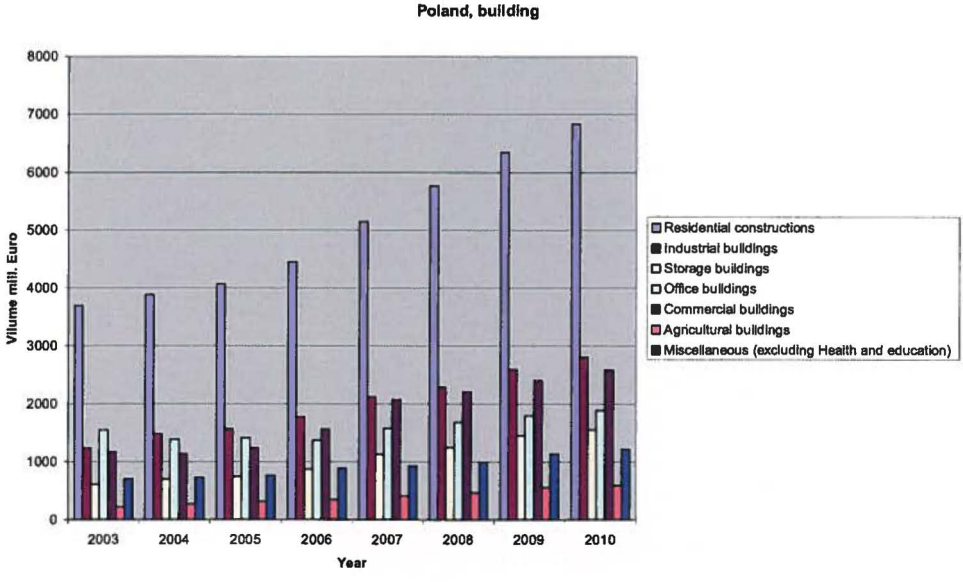

Figure A2.15 Building in Poland in volume million Euro (Czerny & Weingärtler, 2007).

Portugal's population is 10.6 million and the outlook is that it will increase to 10.7 million.

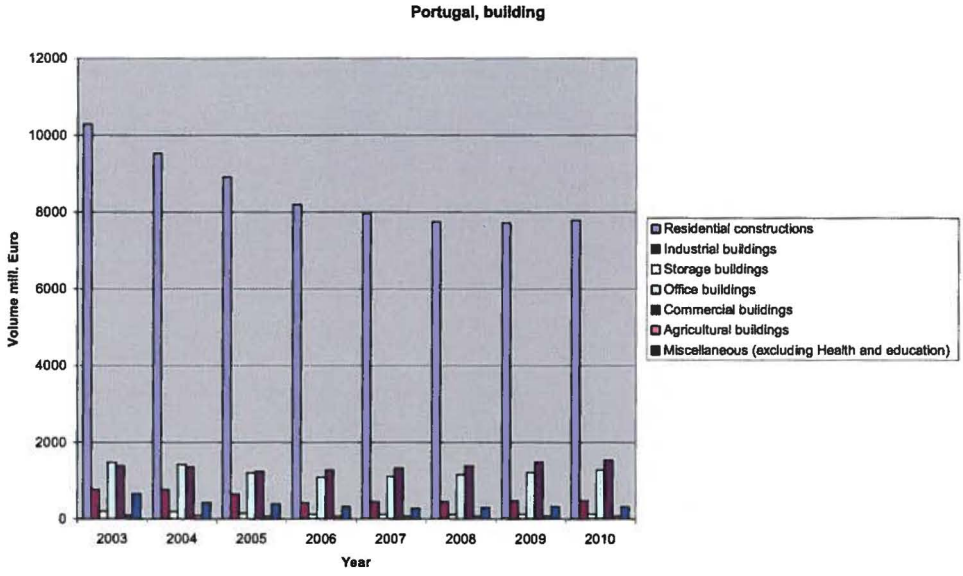

Figure A2.16 Building in Portugal in volume million Euro (Czerny & Weingärtler, 2007).

Slovak Republic's population is 5.4 million and a small increase of the population is estimated with 10 000 people to 2010.

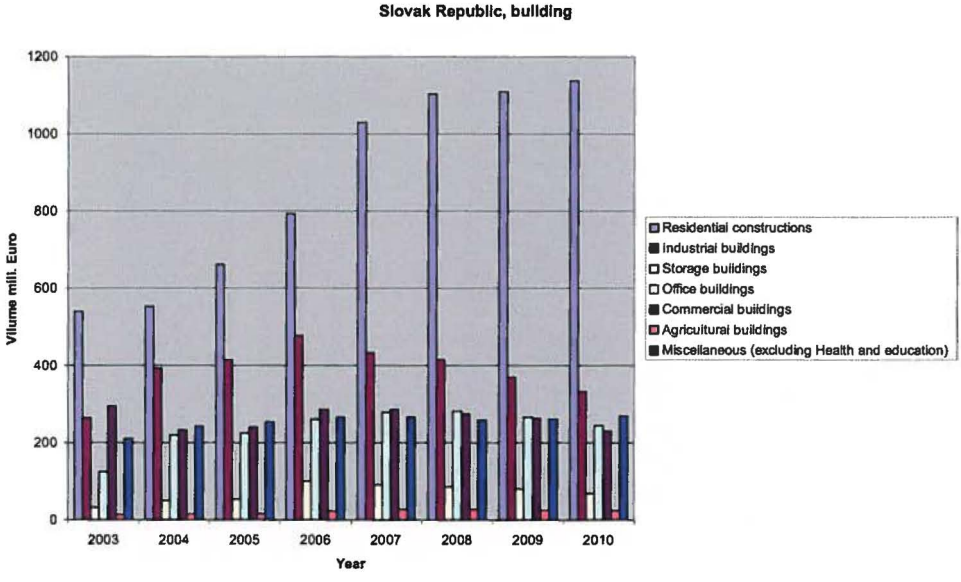

Figure A2.17 Building in Slovak Republic in volume million Euro (Czerny & Weingärtler, 2007).

Spain's population is almost 45.2 million and is forecasted to increase to 46.6 million to 2010.

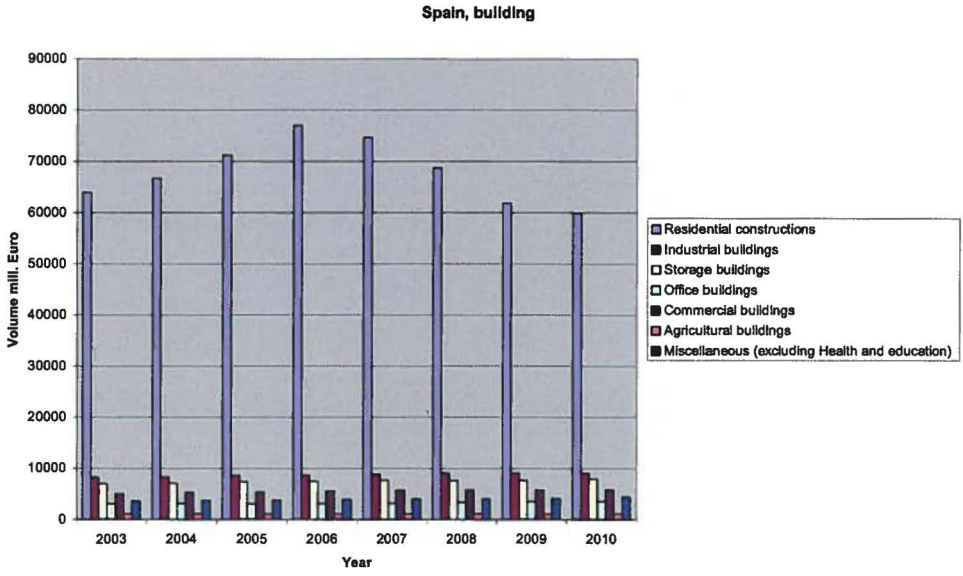

Figure A2.18 Building in Spain in volume million Euro (Czerny & Weingärtler, 2007).

In Spain, housing starts has been as seen in figure A2.19

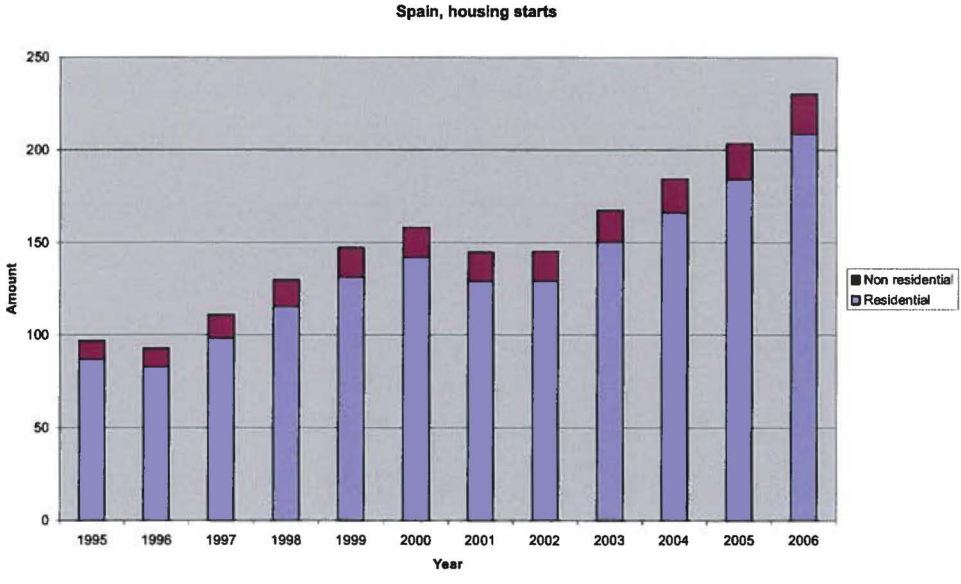

Figure A2.19 Amount housing starts in Spain devided into residential and non-residential (Federal Statistics Office and for year 2005 and 2006 FAS Bonn, 2007).

Sweden's population is 9.2 million and is estimated to increase to 9.3 million to 2010.

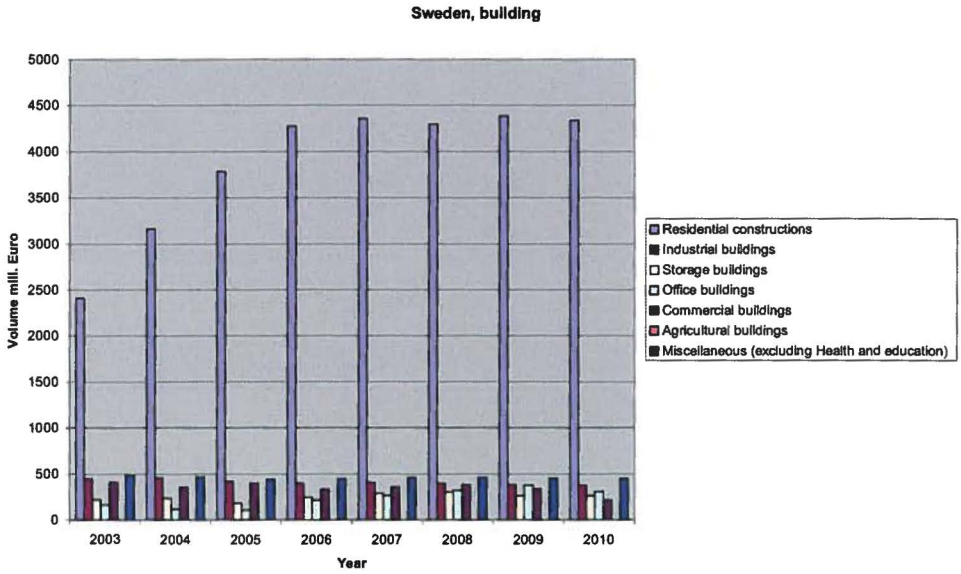

Figure A2.20 Building in Sweden in volume million Euro (Czerny & Weingärtler, 2007).

Switzerland's population is 7.6 million and will be 7.8 million in 2010 according to an outlook.

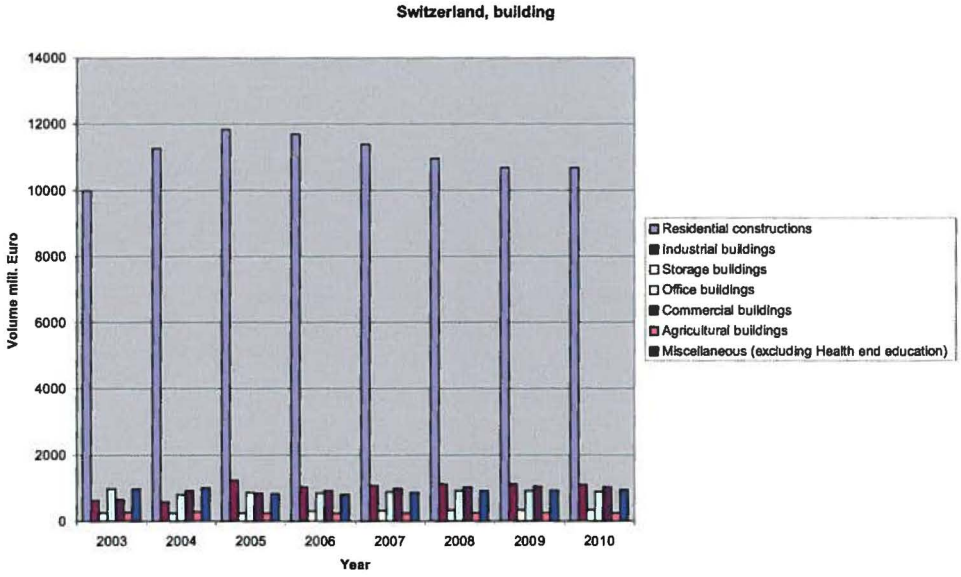

Figure A2.21 Building in Switzerland in volume million Euro (Czerny & Weingärtler, 2007).

The United Kingdom's population is 61.1 million and is estimated to increase to 61.7 million to 2010.

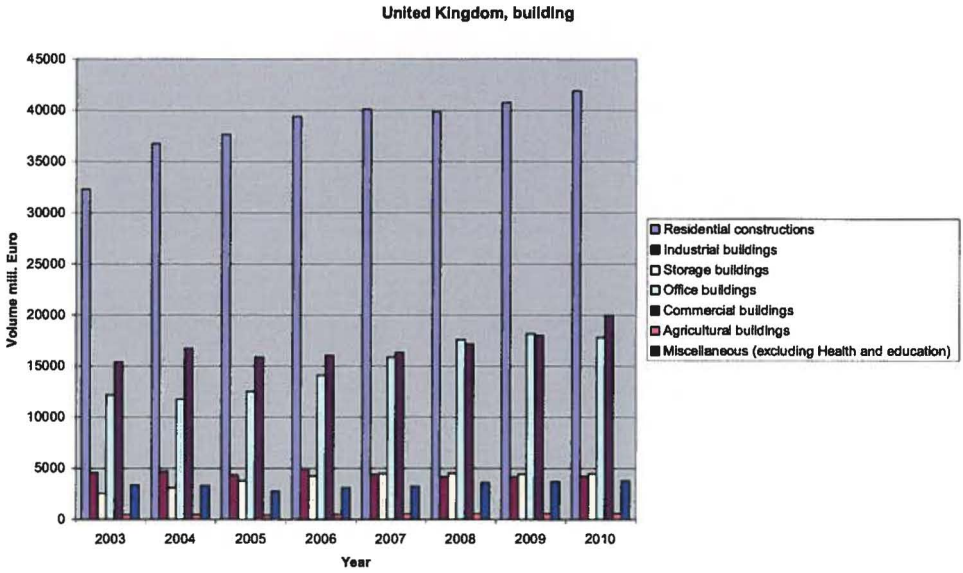

Figure A2.22 Building in United Kingdom in volume million Euro (Czerny & Weingärtler, 2007).

APPENDIX 3. EXPORT OF GLULAM

The majority of Austria's export of glulam goes to Italy and the latest years Japan is number two before Germany, which has third place.

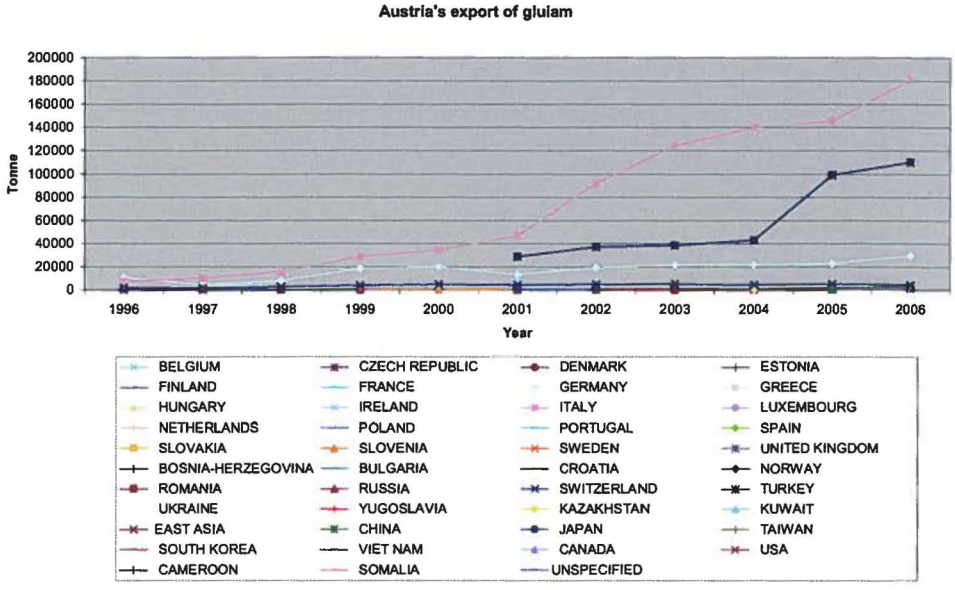

Figure A3.1 Export of glulam from Austria (Svandata, 2008).

Finland is mainly exporting glulam to Japan, but also to Italy, Norway, France and United Kingdom. See Figure A3.2 below.

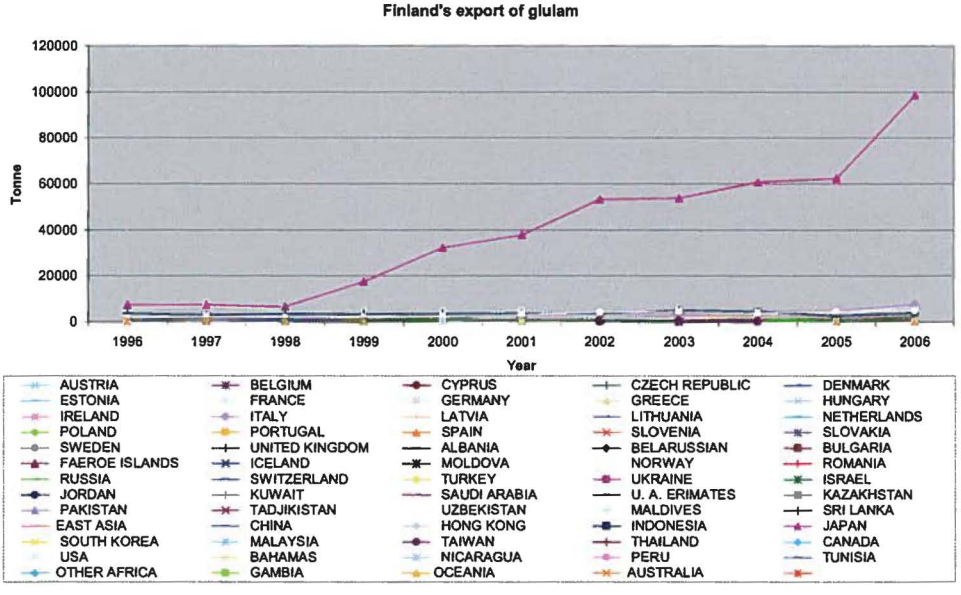

Figure A3.2 Export of glulam from Finland (Svandata, 2008).

France is mainly exporting glulam to Spain, Belgium, Germany, Portugal, Ireland and Switzerland.

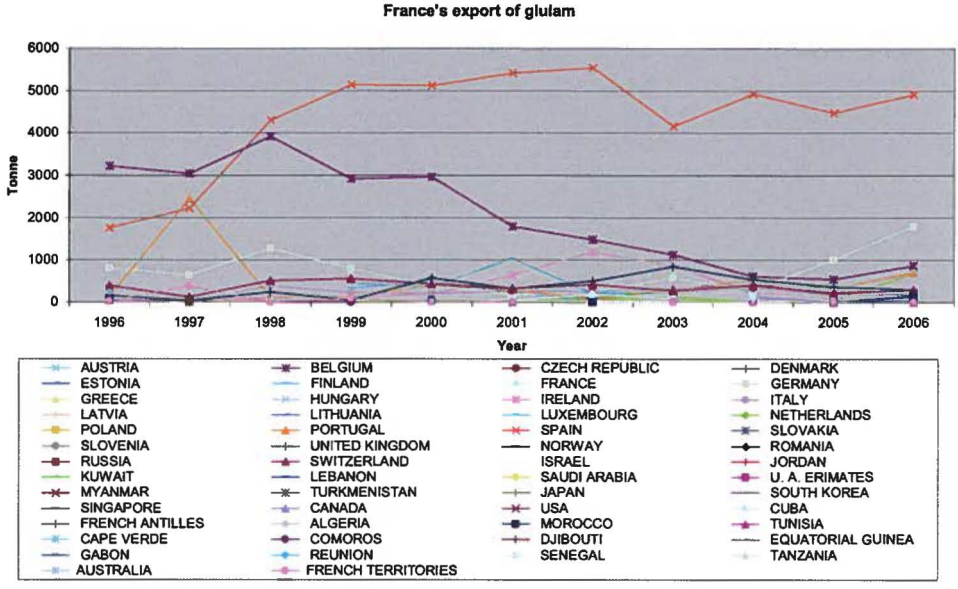

Figure A3.3 Export from France (Svandata, 2008).

Germany's export to Italy has increased much the latest years. The export to Austria is fluctuating some, and have gone from the first and second largest export market to the fourth. Now Switzerland and France is number two and three. Spain, Japan and USA are the following export markets for Germany.

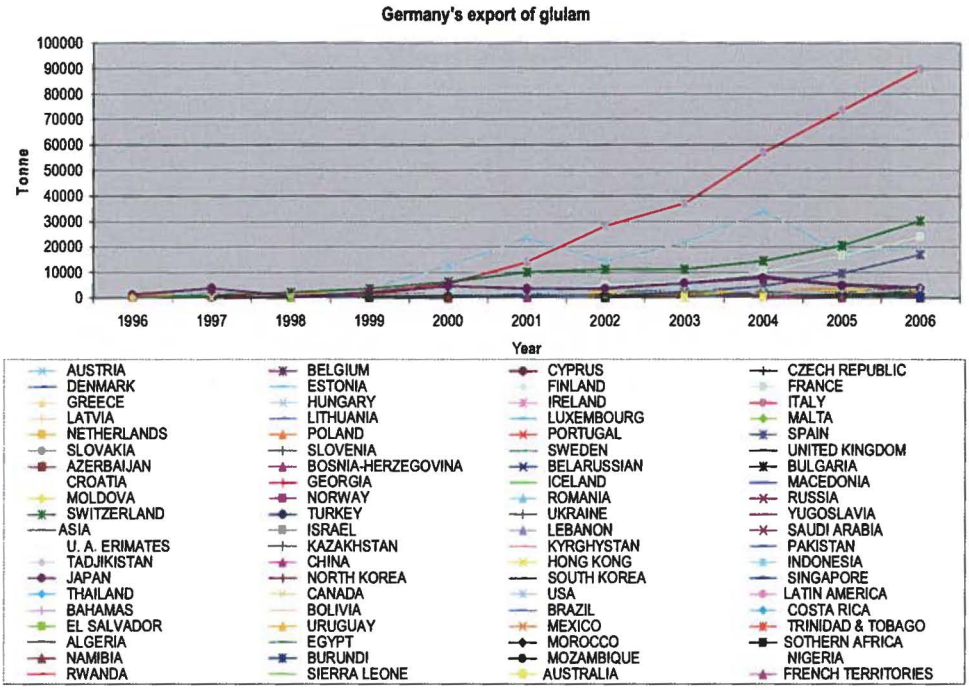

Figure A3.4 Export of Glulam from Germany (Svandata, 2008).

Norway

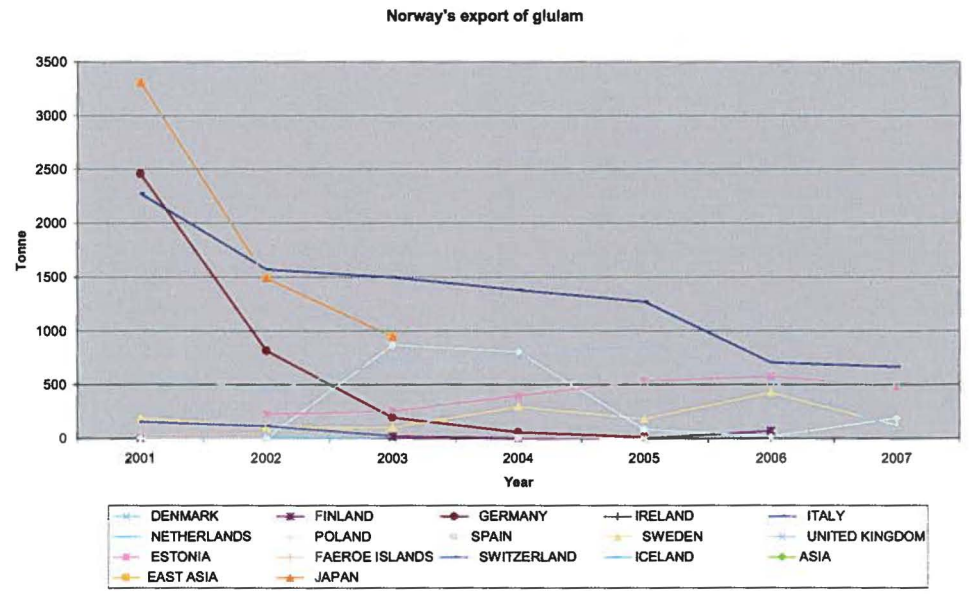

Figure A3.5 Export of glulam from Norway (Svandata, 2008).

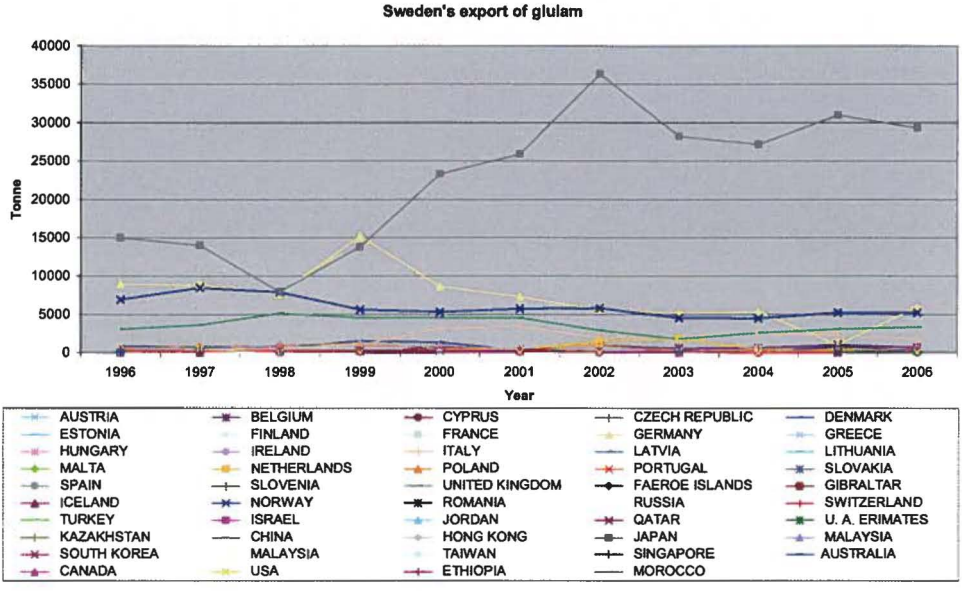

Figure A3.6 Export of glulam from Sweden (Svandata, 2008).

APPENDIX 4. THE COMPARISON CONSTRUCTION CALCULATION[10]

All dimensions are calculated according to SIS, The Swedish Standards Institute (Regelsamling för konstruktion - Boverkets konstruktionsregler, BKR, byggnadsverkslagen och byggnadsverksförordningen) will be called BKR below.

Some of the calculations are from Paul Johansson and Bengt Vretblad's (1995).

The data for the steel's cross section comes from TIBNOR's tables for constructions for pipes, beams and poles.

For the compared building, the required security class for the building is 3.

When the beam's cross section was compared between steel, concrete and glulam, the capacity were only estimated according to the bending stress and the ultimate breaking strength.

Comparison between steel and wood

The moment's cross section can be calculated as $M_d = f_d * W$

Where W is the cross sections resistance to bending and f_d is the material's dimensioned bending strength.

The moment's cross section for wood can be compared to the same for steel as follows:

$W_{wood} * f_{md} = W_{steel} * f_{yk} \rightarrow W_{steel} = (f_{md} * W_{wood}) / f_{yk}$

For rectangular cross sections $W = (b * h^2) / 6$

For the cross section of steel, the values are from TIBNOR's tables for constructions.

Comparison between concrete and wood

The moment's cross section can be calculated as $M_d = f_d * W$

As in the steel and wood comparison, this is made the same way; $M_{dconcrete} = M_{dwood}$

The reinforced concrete cross section is calculated according to "building formulas and tables" from SIS, section 822a.

The relative moment is $\bar{m} = M_{dconcrete} / (b * d^2 * f_{ccd})$

The mechanical reinforced content in the concrete beam $\omega = 1 - \sqrt{(1-2*\bar{m})}$

From this the area of the steel in the reinforced concrete can be estimated:

$As = \omega * b * d * f_{ccd} / f_{st}$

Sources for input values for wood

Glulam L40.

The calculations are based on Table 5:22a in BKR according to the climate (class 1).

Table 5:3121a in BKR for the load duration (were calculated to be B)

The characteristic compressive strength in bending in the fibre direction $f_{mk} = 26$ MPa (from BKR Table 5:23 b)

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[10] Segerman comm. 2008-05-15

The dimensioned compressive strength in bending: $f_{md} = (f_{mk} * \kappa_r) / (\gamma_m * \gamma_n)$ (from BKR 5:3121a)

f_{mk} is also multiplied with κ_h which is a dimension dependet factor

$\kappa_h \leq 1.15$ if $h \leq 300$

$\kappa_h \leq (600/h)^{0.2}$ if $300<h<600$ (from BKR 2:115)

κ_r is a conversion factor that take into account the influence of moisture and the loads duration (from BKR table 5:3121a)

γ_m is the partial coefficient for the material. For the ultimate breaking strength it is 1.25 for wood (from BKR 5:3121)

γ_n is the partial coefficient for the security class. For 3 in this case, γ_n is 1.2 (from BKR 2:115)

Sources for input values for steel

Type of steel beam is S355J2G3.

The characteristic compressive strength $f_{yd} = 355$ MPa (from BKR table 8:221 b)

The dimensioned compressive strength is $f_{yd} = f_{yk} / (\gamma_m * \gamma_n)$ (from BKR 8:312 a)

γ_m is the partial coefficient for the material. For the ultimate breaking strength it is 1.0 for wood (from BKR 8:312)

γ_n is the partial coefficient for the security class. For 3 in this case, γ_n is 1.2 (from BKR 2:115)

Sources for input values for concrete

Type of concrete beam is C32/40

Type of reinforcement is a ribbed bar B500B

The characteristic compressive strength for concrete is $f_{cck} = 30.5$ MPa (from BKR table 7:221 a)

The dimensioned tensile strength for the reinforcement is $f_{yk} = 500$ MPa (from BKR 7:231 a)

The dimensioned compressive strength for the concrete is $f_{ccd} = f_{cck} / (\eta * \gamma_m * \gamma_n)$ (from BKR 7:3121 a)

$\eta * \gamma_m$ is the coefficient for the material. For the ultimate breaking strength it is 1.5 for concrete and 1.15 for the reinforcement (from BKR 7:3121 a)

The dimensioned compressive strength for the reinforcement is $f_{st} = f_{yk} / (\eta * \gamma_m * \gamma_n)$ (from BKR 7:3121 a)

Comparison of column section for wood, steel and concrete

The calculation starts with the bearing strength for the pressure considering the measure of stability and the local pressure on the construction. After this the needed cross section of concrete and steel is compared.

Bearing strength of wooden cross section

$R_{cd} = \kappa_c * f_{cd} * A$ where A is the cross section's area (from BKR 5:3123)

f_{cd} is the wood's dimensioned resistance for pressure parallel to the fibres.

$f_{cd} = (f_{ck} * \kappa_c) / (\gamma_m * \gamma_n)$ (from BKR 5:3121a)

where f_{cd} is the characteristic resistance value (from BKR Table 5:23 b)

κ_c is a reduction factor that consider the risk for cracking.

$\kappa_c \leq 1$ when $\lambda \leq 27$

$\kappa_c \leq k + \sqrt{(k^2 + \lambda_r^2)}$ when $\lambda > 27$

and $k = 0.5 * (1 + \beta (\lambda_r - 0.5) + \lambda_r)$ and $\lambda_r = \sqrt{(f_{ck} / E_{Rk})}$ and $\lambda = l_c / i$ where l_c is the critical breaking length. In this calculation 2.7 m are the critical breaking length.

The cross sections radius of inertia is i.

Bearing strength of steel cross section

This has been taken from TIBNOR's tables for construction.

Bearing strength of concrete cross section

The poles of concrete's bearing strength when the pressure is centrically, are from "byggformler och tabeller, section 862"

$Nu = k_c * A_c * f_{ccd} / (1 + k_\varphi * \varphi_e) + k_s * A_s * f_{st}$

Calculations

Here the calculations are shown. First the strength that the glulam construction need is calculated, then this value is compared to see which type of concrete and steel would be needed for a frame in that material that would carry the same weight. When choosing the steel and reinforced concrete, the types are chosen that are common to use.

Beams

<u>Type 1: Glulam beam size 215 x 585</u>

The glulam beams are rectangular and are made of wooden lamellas that are glued together.

$\kappa_r = 0.75$

$f_{mk} = 26$ MPa

$L_{tot} = 424$ m

$V_{tot} = 53.3\ m^3$

$W_{max} = 12\ 263 * 10^3\ mm^3$

$K_h = 1.005$

$f_{md} = 13$ MPa

→ $M = W_{max} * f_{md} = 159$ kNm

Steel is s355 HEA 220

The steel beams looks like an H in the cross section

$A = 6434\ mm^2/m$

$f_{yd} = 296$ MPa

$f_{yd}/f_{md} = 296/13 = 22.8$

$W_{max}/22.8 = 539 * 10^3\ mm^3$ Compare this value with $W_x = 515 * 10^3\ mm^3$

Reinforced concrete C32/40 and reinforcement Ks600s 600x500 6Ø16

The reinforcement is on the side of the concrete beam where the forces will stretch the beam since this is needed when using concrete.

$f_{cc} = 16.9$ MPa

$f_{st} = 435$ MPa

$\bar{m} = M_{dconcrete} / (b * d^2 * f_{ccd}) = 159 * 10^3/(0.3*0.4^2*16.9*10^6) = 0.196$

$W = 1 - \sqrt{(1-2*\bar{m})} = 0.22$

$A_s = w * b * d * f_{cc}/f_{st} = 1027\ mm^2/m$

→ 6Ø16 (1206 mm^2/m)

Type 2: Glulam beam size 115 x 415

$\kappa_r = 1.07$

$f_{md} = 14$ MPa

$L_{tot} = 225$ m

$V_{tot} = 10.7\ m^3$

$W_{max} = 3300 * 10^3\ m^3$

$M_{max} = 46$ kNm

Steel HEA 140

$A = 3142\ mm^2/m$

$W_x = 155 * 10^3\ mm^3$

Reinforced concrete 200x450 3Ø16

$A_{cct} = 0.09\ m^2/m$

$A_{reinforced\ steel}$ =603 mm^2/m

Type 3: Glulam 140x765

$\kappa_h \approx 1.0$

f_{md} = 13 MPa

L_{tot} = 26.4 m

V_{tot} = 2.83 m^3

W_{max} = 13655 *10^3 mm^3

M_{max} = 178 kNm

Steel HEA 240

A = 7684 mm^2/m

W_x = 675 *10^3 mm^3

Reinforced concrete 300x500 6Ø16

A_{cct} = 0.15 m^2/m

$A_{reinforced\ steel}$ =1206 mm^2/m

Type 4: Glulam 140x630

$\kappa_h \approx 1.0$

f_{md} = 13 MPa

L_{tot} = 52.8 m

V_{tot} = 4.66 m^3

W_{max} = 9261 *10^3 mm^3

M_{max} = 120 kNm

Steel HEA 200

A = 5383 mm^2/m

W_x = 389 *10^3 mm^3

Reinforced concrete 300x500 4Ø16

A_{cct} = 0.15 m^2/m

$A_{reinforced\ steel}$ =804 m^2/m

Poles

Type 1: Glulam 215x360

L_{tot} = 464 m

V_{tot} = 35.9 m^3

l_c = 2.7 m

$R_{cd} = \kappa_c * f_{cd} * A$

f_{cd} 0.75 * 24 = 18 MPa

A = 0.0774 m^2

$i = h/\sqrt{12} = 215/\sqrt{12} = 62$

$\rightarrow \lambda = l_{cr}/I = 2700/62 = 44$

κ_c=1.0 $\rightarrow$ R_{cd}=1393 kN

Steel VKR 220x120x10

According to TIBNOR 2.5 m poles can carry maximum 1390 kN

A = 62 90 mm^2/m

Reinforced concrete 300x300 4Ø12

$Nu = k_c * A_c * f_{ccd} / (1+ k_\varphi * \varphi_e) + k_s * A_s * f_{st}$

$k_c = 1$

$k_s = 1$

$k_e = 1$

$\varphi_e = 3$

A_{cct} = 0.09 m^2/m

$A_{reinforced\ steel}$ =452 mm^2/m

Stability

Glulam 33x2500

L_{tot} = 325 m

V_{tot} = 26.8 m^3

Steel ~L60x60x10

120 m

A = 1110 mm^2/m

<u>Reinforced concrete</u>

120 m

A_{steel} =1110 mm^2/m

Results from the comparison

<u>Glulam L40</u>

V_{tot} = 134.2 m^3

Glulam's weight is about 500 kg/m^3

→ Total weight 67 Tonne

<u>Steel S355J2</u>

V_{tot} = 2.73+ 0.71 + 0.2 + 0.28 + 2.92 (from VKR) + 0.13 = 6.98 m^3

Steel's weight is about 7800 kg/m^3

→ Total weight 54.4 Tonne

<u>Reinforced concrete C32/40 and reinforcement B500B</u>

V_{cct} = 63.6 + 20.5 + 4 + 8 + 41.8 = 138 m^3

Concrete's weight about 2400 kg/m^3

→Total weight of concrete is 331 Tonne

V_{steel} = 0.51 + 0.14 + 0.03 + 0.04 + 0.21 + 0.13 = 1.06 m^3

Steel's weight is about 7800 kg/m^3

→ Total weight of the reinforcement is 8.3 Tonne

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