DASOS CAPITAL

REVIEW OF WOOD-BASED CONSTRUCTION AND ARCHITECTURE - TECHNOLOGY, STATUS AND TRENDS

Nora Anttonen

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FOREWORD

New regulation for the use of wood in multi-storey buildings (5-8 floors) in Finland was executed on the 15th April 2011. The reform triggered the ongoing wave of wooden multi-storey building projects in the country. Although this last reform represented an important step towards applying wood as a construction material in ever demanding targets, the history of "modern" wood-based architecture is in fact older, and it was initiated in the early 1990s as an EU cooperation project.

Currently, wood is applied increasingly as a construction material rather widely across the EU countries. However, the development patterns of wooden housing do vary greatly by region in Europe. The transition from the ancient wooden farmhouses towards modern wood architecture with multi-storey urban buildings evolved particularly smoothly in some specific areas. In Central Europe, wood has maintained its share in the continuously shifting architecture frontier over the years. In contrast, in the forest-rich Northern countries the path from the past to the current building trends has been characterized by remarkable discontinuities from the viewpoint of wood use. Here, the dominating architecture schools at the times often only scarcely valued wood as a material for multi-storey buildings - until recently. In future, it seems likely that the wood-based architecture will increase its market share driven by such megatrends as ecological living and green building as well as substantial advancement in the wood construction technology.

With some 20 years of accumulating and accelerating development, the modern wood-based housing and construction represents a growing and high-value market for Dasos wood. In order to highlight the contemporary state, technology, and trends, Dasos invited in June 2015 Ms Nora Anttonen, student at KTH Royal Institute of Technology, School of Architecture and Built Environment in Stockholm, Sweden, to carry out a study on wood architecture with focus in Finland. The work has been supervised by Dr Marko Katila, Senior Advisor at Dasos Capital Oy Ltd.

The study was performed by visiting tens of wood-based buildings and analyzing implemented technical solutions, interviewing several leading experts in the field, as well as by extensive literature review. The present report aims at summarizing key findings. We thank Nora for her excellent work with the project.

We hope that the report will provide informative reading to all with interest in the current status and future prospects of wood-based construction.

Helsinki, the 10th November 2015

Dasos Capital Oy Ltd

Olli Haltia

Cover photo: Helsinki Central Library by ALA Architects

The Helsinki Central Library's construction work started on the 1st of September 2015 and the library will be completed by the end of year 2018.

The building façade will constitute glass and wood. Pre-assembled elements made from local materials will be used to construct the wooden façade. The cladding will be made of 35 mm-thick, first-grade spruce. The building performs two contrasting spaces that are created by an arching wooden volume. The wooden volume is stretched vertically to create connections to the open main floors below and above.

IMPORTANT INFORMATION

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DASOS CAPITAL OY

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ABBREVIATIONS AND ACRONYMS

ARA	The Housing Finance and Development Centre of Finland
BREAM	Building Research Establishment's Environmental Assessment Method
CLT	Cross laminated timber
CO_2	Carbon Dioxide
EU	European Union
GBC	Green Building Council
GHG	Green house gas
LEED	Leadership in Energy and Environmental Design
LVL	Laminated Veneer Lumber
MSO	The Strategic Programme for the Finnish Forest Sector
PTT	Pellervo Economic Research
SAFA	Finnish Association of Architects
TED	Technology, Entertainment, Design
TEM	Ministry of Employment and the Economy
TES	Timber Element System
US	United States
USD	United States Dollar

1. INTRODUCTION

This report examines the possibilities of wooden construction taking the contemporary state and trend into account. In addition to stressing the Finnish perspective, a chapter of global overview is included.

The first chapter discusses the advantages of wood as construction material. The chapter about construction technologies and products seeks to create an overall image of the main existing techniques. The aim of examining the state of Finnish wooden construction and doing an international overview of the recent developments is to generate a view on the future possibilities and trends. The last chapter provides examples of existing and planned wooden buildings and constructions through case examples and photographs from the visits done as a part of this project. There are also graphs and other figures that visualise the statistical information.

2. ADVANTAGES OF WOOD

The advantages of wood as a construction material are versatile. For the society, using wood in public constructions brings economic benefits as the employment level increases, and exports of wooden products grow, etc. For the user, the resident, wood is a pleasant material, and is discovered to have many positive impacts on health. In addition, the ecological advantages for the society will have a growing importance.

2.1 Construction

Compared to other materials, wooden construction is a relatively fast process. Using prefabricated elements minimizes the construction time at the site. It is also a less noisy process compared to other materials.

When the elements are produced indoors the circumstances are significantly easier and the materials are not exposes to weather changes, and neither is there a need to wait for the drying of concrete. As the elements are custom made, it allows them to be assembled quickly. All in all, the construction site, the assembling process is easier, safer and more effective (Tolppanen, J. et al. 2013). The construction speed of a wooden multi-storey building can be up to one half compared to other materials.

Wood allows the use of lighter structures. It is a solid material, thus the use of wood in constructions give more living space compared to other materials. For example, when using Cross Laminated Timber (CLT), there can be up to 10% more space (*StoraEnso.com*). That is a significant advantage, especially when the demand of small apartments and houses is increasing.

The effectiveness and rapidity bring many economic benefits as well. In addition, wood is often economically the most reasonable material (*Puuinfo.fi*). On the contrary, the contemporary Finnish regulations concerning only wooden multi-storey houses create extra costs, which can make construction of multi-storey buildings approximately 5 to 7 % more expensive compared to concrete due to e.g. obligatory sprinkler systems (Mikkola, M. 2015. However, these costs are compensated over the life cycle especially when environmental benefits are included.

When more wood is used - especially in public construction projects - its value added grows. That again supports domestic economy, as it decreases the need of imports and simultaneously brings more tax incomes and increases employment level throughout Finland (Tolppanen et al. 2013). Compared to other materials, wooden construction utilizes more domestic work (Hietala, J. et al. 2015). In total, according to the Pellervo Economic Research (PTT) survey, when the amount of wood increases in public contracts, it has positive consequences to the national economy.

In addition, wooden construction is an important potential export branch, which could definitely bring growth to Finnish economy, as the situation of diminishing raw materials sets up challenges around the globe, and there is a need for new solutions (*Puuinfo.fi*).

2.2 Environment

Buildings, their construction and raw materials used in construction are a significant source of carbon dioxide emissions globally and consume a lot of energy. Buildings account for 40% of total energy consumption and 30% carbon dioxide emissions in the European Union (EU). Globally, construction as a whole, including manufacture of construction materials, construction and use of buildings, accounts up to 40% of the green house gas (GHG) emissions, and 40% of the energy consumption. Construction activity is increasing due to population growth, urbanisation, migration and rising living standards, and hence the use of energy and materials from renewable sources, including wood, in the building sector has emerged as an important approach to reduce GHG emissions and improve energy-efficiency. Wood is an eco-friendly material in many ways. That makes a wooden building

ecologically sustainable throughout its lifecycle. Wood is renewable and natural, and it functions as a carbon sink, thus enhances the air quality.

Scientific findings indicate that a wooden building can reduce significantly its carbon load compared to an equivalent building made from concrete reinforced with steel, and reduce the use of natural resources and energy per constructed housing unit over the lifecycle. Wooden buildings act also as carbon sinks (Bribian et al. 2011; Koskela et al. 2011; Sathre et al. 2010). Timber came on the top in the study 'Environmental Profiles of Building Materials, Components and Buildings' - one of the first substantive exercises undertaken by a major independent research body into the of life cycle assessment (LCA) of building materials (Building Research Establishment 2015). Timber scored highly in the 13 environmental impacts studied — from climate change, pollution to air and water, waste disposal, and transport pollution and congestion. According to the study, timber is the only building material to have a positive impact on the environment, with trees' ability to absorb carbon dioxide and emit oxygen.

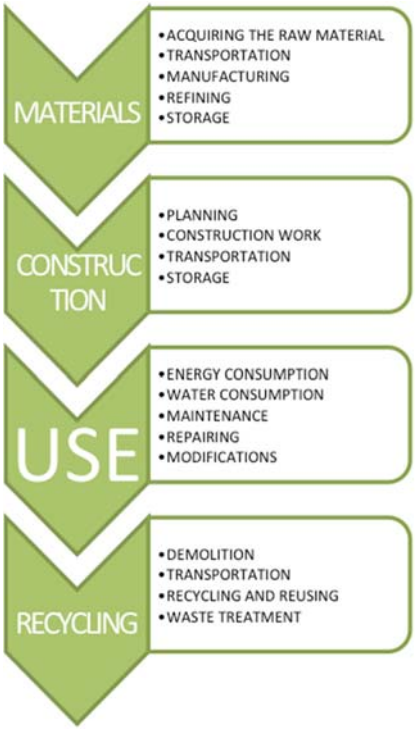
The production of wooden building materials: it often utilizes renewable energy, creates relatively less environmental damage and the amount of material waste is minimum (Tolppanen, J. et al. 2013).

Transporting the wooden material is more efficient and less polluting because of the lightweight of the materials and the domestic availability (*Puuinfo.fi;* Tolppanen et al. 2013). Because of the same reason, the cranes needed in the assembling process do not have to be as massive and powerful as in concrete construction.

As a completed building, wood still is very ecological. It has the feature of storing carbon from the air, which is a significant environmental advance compared to other construction materials. However, the total energy consumption of the building depends on the people and their living behaviour. Ultimately, there is the possibility to reuse the material after demolishing the building: wood can be recycled or used in energy production. In comparison, parts from the old concrete buildings can be crushed and reused, e.g. in outdoor architecture, such as parks.

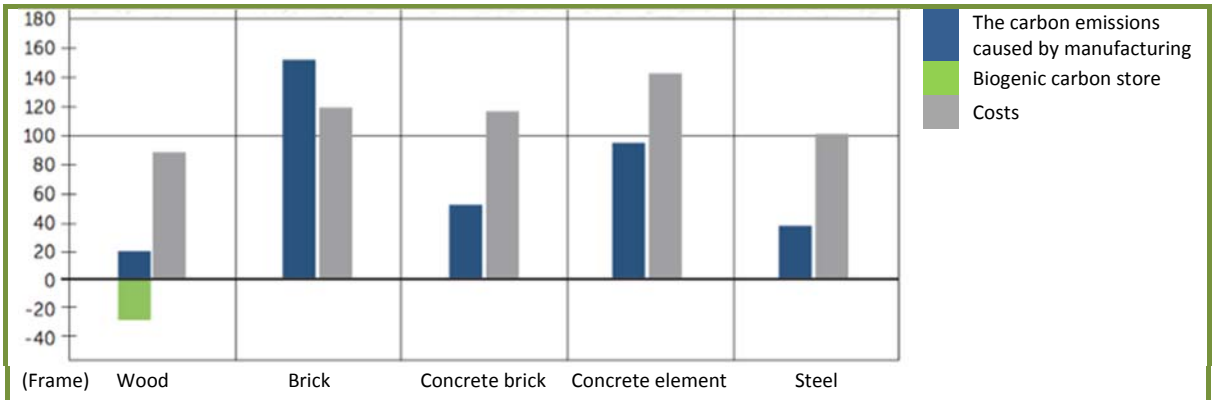
In the whole European Union area, wood is consumed less than it grows (Tolppanen et al. 2013). Thus, more wood could be used without putting the sustainability of resources into danger. According to multiple references, replacing other construction materials by wood is a way to improve the state of environment. Changes to the construction solutions and technologies are needed, in order to reach the goals of reducing emissions, which are set nationally and in the EU and global level as well.

Figure 1 Life Cycle Phases of a Building



Source: Puuinfo brochure: The ecological footprint of buildings

Table 1 Comparison of the Carbon Footprint and Building Cost



Relationship between carbon footprint and building costs for wall construction. The carbon footprint is generated by adding together the emissions produced during the manufacture of the material. The costs consist of those for materials and those for work. The U-value of the constructions being compared are the same. Constuction components costs are from 2013, emission calculations are author's.

Source: Puuinfo 2/15

2.3 Health Impacts

A large amount of positive results are found from the examinations of the health effects of wood as a construction material of buildings. Not every cause is yet scientifically found, but at least experimental findings support the features of wood in health encouragement.

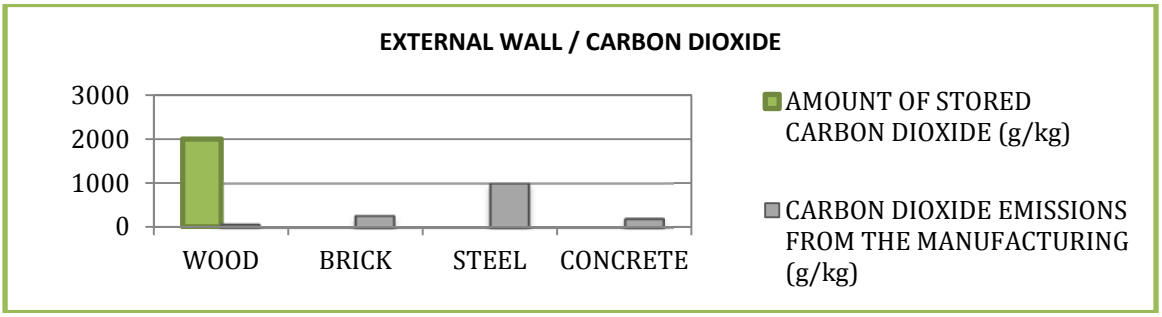
Wood controls humidity, thus used in interior building materials wood creates a pleasant and healthy indoor climate (Simonson, C. J. et al. 2001). In addition, wood reduces stress, thus it enables the creation of healthy,

comfortable and durable spaces (Muilu-Mäkelä, R. et al. 2014). The stress reducing effect creates a great potential, as it promotes wooden materials to be used e.g. in school and office buildings. The better pupils and employees enjoy the milieu and atmosphere, the more productive they are. That again has further effects on the society, in socio-economic means.

Other important advantages are the antibacterial features of wood. It can be used to reduce the problems with mould and allergies. Especially log construction has been is praised to be very anti-exposed to mould. That is one reason why that traditional construction style has had positive attention and the use of it is somewhat increasing.

From the users' point of view, wood as a natural material is comfortable, warm and aesthetic. The wood odour is in general considered convenient, as it somewhat brings the nature indoors. Also the acoustics of wood are pleasant, and can be exploited in many different ways, such as concert halls. According to the people living in wooden multi-storey houses, the sound milieu is silent, and there does not appear echo (*Puuinfo.fi*).

Figure 2 Carbon Dioxide Storage and Emissions with Different Materials



Source: Puuinfo brochure: The ecological footprint of buildings.

2.4 Is Wood Fire Safe?

Against the common belief, wood is a safe construction material. The advantage of wood in a fire situation is that it chars steadily, which slows down the spreading of fire (Hirsi, H. 2012).

In Finland, the fire code was modified in 2011 to enable the construction of multi-storey wooden buildings up to eight storeys, although there are special regulations for wooden buildings, including sprinkler requirements. However, the wooden the construction products are regarded very fire safe. In a case of fire, the steady charring of wood material makes the endurance and behaviour of the structure easy to predict. In addition to the sprinkler system, there are ways to structurally protect the wood. Most commonly, the material is covered with a drywall, which keeps the temperature low and keeps the fire away from the wood material for a certain amount of time (*Puuinfo.fi*).

The endurance of different construction materials is carefully examined. The predictable reactions of wood in fire allow the calculation, but also physical tests are made. Metsä Wood for example has tested all its wooden construction products by test burning them, tells Marko Kellberg from Metsä Wood.

Table 2 How Do Different Materials React to Fire

Wood	• Charring 0.8 mm / min → slows down the burning
Steel	• Non-flammable • Strength declines
Concrete	• Cracking
Burnt brick	• Non-flammable
Concrete bricks & masonry stones	• Well fire resistant

Source: Hirsi, H. 2012

Table 3 Case Hempcrete

When it comes to the un-ecological features of concrete, it must be recognised that new,technologies are being developed in that field, too, making also use of wood-based materials. Bio-composite, hemp concrete, thus *hempcrete,* is one example of developing new construction materials based on the traditional ones.

Hempcrete is made of hemp mixed with lime-based binder. It is not used as a structure itself, but as infillings and such. Wood works as an ideal stiffening material to hempcrete. The material weights only about 15% of the traditional concrete, which facilitates the transportation. The material is fire safe, it has good insulation and air quality features, and it absorbs carbon dioxide (CO_2).

Sources: hemprefine.fi, americanlimetechnology.com

Table 4 Case Bamboo

Ibuku is a Bali-based designer team promoting the use of bamboo in construction. The team was first brought together in the project of building a green school in Bali around 2007. The team constructs bamboo houses and buildings in the Bali area. The head of Ibuku, Elora Hardy, introduced the potential of bamboo to the wide international audience in a TED (Technology, Entertainment, Design) talk in March 2015.

Bamboo grows extremely fast. It is a strong material as well, with the "compressive force of concrete and the strength-to-weight ratio of steel". When it comes to protection from insects and rotting, the new treatments take care of that and enhance the durability of the material with ecological methods.

Source: ibuku.com

Table 5 Case Metsä Wood's Plan B

Metsä Wood has launched a project called Plan B, where they have architects re-designing existing iconic buildings to be constructed from Kerto® and their other wood products. The purpose is to show that anything is possible – wood has no more limits than any other material. Currently, there are e.g. the cases of re-designing Colosseum and Empire State Building using wood.

Source: www.metsawood.com

3. TECHNOLOGIES

At the moment, the main wooden construction products are cross-laminated timber (CLT), LVL (laminated veneer lumber, Kerto®), glulam and I-beams. Especially CLT has been a common material in the new wooden multi-storey houses, often in form of element modules. There are different modification technologies to ensure the durability of the wood.

3.1 Introducing the Products

3.1.1 Cross Laminated Timber (CLT)

CLT is a solid wood panel, made out of single-layer panels glued at right angles to each other. The thickness of the product can be selected depending on the purpose of use (from three layers up to eight). CLT can be used e.g. in ceilings, floors and walls, both internal and external. The load-bearing capacity of the CLT panels is high.

There are basically no limits of style or architecture in the use of CLT; the material can be shaped as wanted. In the façade, the wooden surface can be left visible, or covered with any chosen material.

The main suppliers of CLT in Finland are Stora Enso and CrossLam. Stora Enso imports the products from Austria, while CrossLam is the first manufacturer of CLT in Finland. Their products are fabricated in Kuhmo, Finland, from domestic wood. Examples of buildings constructed with CLT include Joensuun Elli, Puukuokka, and Haltia Nature Centre (see Chapter 6)

Due to its fast construction and assembling time, CLT is a potential material in catastrophe areas and emergency housing. CLT provides a quick solution to the desperate need of replacing homes. The buildings constructed as replacements do not have to be temporary, as CLT is a durable material, even in areas with seismic activity (*crosslam.fi*).

Earthquake resistance

CLT is also a good construction material when it comes to earthquake safety. It is strong, but yet somewhat flexible. In Japan, a 7-storey CLT building was tested in 7 Magnitude earthquake conditions; the building stayed unbroken.

Source: crosslamtimber.com

3.1.2 KERTO® and Laminated Veneer Lumber

The LVL is made out of veneer 3 mm thick glued together. Metsä Wood's Kerto® is a laminated veneer lumber product, which can be used in all types of construction. There are different Kerto® products for different purposes, e.g. load-bearing and non-load-bearing structures, walls, floors, etc. Kerto products are used in form of beams and panels.

Metsä Wood's Kerto® is produced in Finland, from Finnish wood. Stora Enso will open a new production line in Varkaus in 2016, where they will start producing LVL panels. Beside the CLT products, LVL will provide slightly different possibilities for the use, thus make the supply even more comprehensive, tells Janne Manninen from Stora Enso. The material will come from Finnish forests.

Examples of buildings constructed of Kerto® wood are Metropol Parasol in Seville, DB Schenker terminal building and FMO Tapiola (see Chapter 6).

3.1.3 Glulam

Glued laminated timber, glulam, is a structural timber product that consists from at least two sawn timber lamellas glued together. Glulam products are generally posts and beams, with the possibility of adjusting the length and thickness depending on purpose. Glulam products can be up to two meters in height and as much as 30 meters in length. It is a very strong material, thus often used in load-bearing structures. The use has relatively few limits, as the beams can be straight, cambered or curved. Compared to its strength, the product is lightweight, and is also easy to combine with other materials.

Glulam is used especially in large-scale buildings and constructions, such as halls, schools and bridges, but also smaller houses can be made of glulam. Metsä Wood's glulam has been used e.g. in the Viikki Church in Helsinki. Stora Enso's glulam posts and beams are made especially for Japanese market, particularly in housing.

Versowood offers standard and project glulam products made of Nordic wood, produced in Finland. The glulam structures in Lahti Sibelius hall are made with Versowoods products (*Puuinfo.fi*).

3.1.4 Log Construction

Log construction is an original tradition in places where straight wood material has been available. In a log building at least the load-bearing structures are made of logs. There are different log types; the specific form of cross section and size of the log depends on the manufacturer. A basic division of log types is however solid logs and laminated logs, and again planed logs and round logs. There are many different styles of making the joints. Logs can be arranged either horizontally (most common in Finland) or vertically. When using vertical arrangement, the sinking and settling of the wood are avoided. Otherwise, the sinking has to be taken into account in the construction process (*Wood Magazine 2/15*).

Log construction has been traditionally used in summerhouses, but now it is getting attention in other areas as well, e.g. the soon-to-be-completed the school campus in Pudasjärvi in northern Finland. In addition, log construction has become more common in modern residential houses lately. Wood material can be combined with e.g. glass, to create light, open spaces.

3.2 Modification

As a natural material, wood is quite sensitive, so it needs to be protected well to ensure durability and safety. Especially in exterior use in Finland, the weather changes need to be taken into account– the materials are continuously exposed to all kinds of conditions: rain, snow and sun. Different ways to modify the wood have been developed.

- **Heat treatment** is a process where wood is treated with high temperature and steam to enhance its durability. The patented process ThermoWood improves the durability of wood technically and also visually. It is an ecological process as no chemicals are used. The process can be used in interior and exterior materials. The method is developed in Finland, and hence it has a patent, only certain companies (including e.g. Metsä Wood and Stora Enso) have the right to use the trademark ThermoWood.
- **Chemical treatment** has been a common process to enhance the durability of wooden materials, especially in exterior use. Back in the day, the chemicals that were used were not eco-friendly, but nowadays the producers are aware of the environment and the causes of using chemicals. Today, producers use commonly environment friendly treatments, which also facilitate the recycling process in the end of the lifecycle of the product.

Case: Kebony

Kebony is a patented modification process invented in Norway. The chemical process gives the sustainable softwood material the features of tropical hardwood. That promotes enhancing the use of wood, as it diminishes the importance of the type of the wood: it improves the features and broadens the possibilities. It has been used in buildings, outdoor furniture, utility articles, etc.
http://kebony.com/

Case: Charring

The charring of wood has been a traditional treatment to make wood material more durable. The process makes the wood more resilient to dry rot and microbes. In Japan, the old tradition of charring includes washing and brushing the surface after the flaming treatment. That makes it non-staining, thus it can be used even in interiors e.g. saunas. Café Birgitta in Helsinki has a charred façade, and the Helsinki Guggenheim is designed to have one as well.
http://www.saunasavu.com/

3.3 Modular Construction

Quick construction time is a significant advantage of wood. Prefabricated, cut to size elements and modules make it possible to minimize the work and time at the construction site. The modules can be assembled quickly; construction time can be cut to half. Hence it saves time, it saves labour force and money as well. The elements or modules are often made of CLT or Kerto/LVL.

Highly prefabricated space elements or modules, are common especially in multi-storey buildings. In some cases, e.g. in hotel or office buildings, the modules can even have a ready-to-use interior. That makes the building ready to use in a remarkably short time, compared to e.g. a concrete building. In Finland, for example Stora Enso and LapWall offer CLT modules. In Sweden, the use of prefabricated modules is a common way to build wooden multi-storey houses.

In addition to the “block modules”, there are large prefabricated elements, e.g. wall and ceiling panels - just to assemble on the site. Metsä Wood’s offers large elements made of Kerto wood.

In renovation constructions, modules are an ideal solution when adding a storey to a multi-storey building. Wooden modules are relatively lightweight and easy to lift on top of the building. For example Koskisen Oy provides wooden extra storeys.

3.4 Designing Programs

The work of an architect is no more done with a pencil on a paper. Digital programs are nowadays the essential tools in designing buildings and their structures. There are many types of programs, and new ones are developed continuously.

The use of algorithms in wooden construction has been examined in a project called DigiWoodLab, conducted by the faculty of Architecture in the University of Oulu. As a part of that, a publication *Algorithms in wooden structures* was released. It introduces the world of algorithmic design, and provides technological information, as well as explains the process of digital fabrication. Significant amount of work is preserved, when the calculation is digitally assisted, and the fabrication of the materials is custom made by robots or 3D printers. The publication includes also existing examples of small-scale and large-scale constructions where these methods are used. The famous Metropol Parasol pavilion in Seville is a good example (see Chapter 6).

Structural calculations have to take the material into account. Stora Enso and Metsä Wood have their own programs, available on their web pages free of charge, to make the structural calculations when using their wooden construction products. *Finnwood* is a tool to make the structural calculations when building with Metsä Wood construction products, while Stora Enso has a CLT designing program. In addition, Stora Enso offers preliminary design tables to facilitate the preparatory designing work when using CLT.

4. INTERNATIONAL OVERVIEW

Wooden construction has been lifting its head globally in the recent years. The total share of wood as a construction material is however still relatively small. Different countries are in different levels of the "material evolution"; there are also cultural differences which affect material use. However, it can be argued that timber-based construction is increasing in general, including increasingly refurbishment.

The growing trend of ecodesign is a phenomenon that increases the attractiveness of wood to a wide audience, and may improve the public attitude towards wood. National wood prizes have also an encouraging influence to increase the use of wood by adducing high quality wood architecture and design.

International environmental goals require acts on cutting emissions, in which construction has a significant role. The increase of using wood as a construction material has been considered as one important manner to improve the state of environment throughout the world. Policy (regulatory), technological, economic and social drivers influence the demand for wood materials in construction, including renovation of old buildings.

In 2010, the EU introduced a Roadmap for Moving to a Competitive Low Carbon Economy in 2050 which sets very ambitious targets for reducing GHG emissions from residential buildings by about 50% by 2030 and 90% by 2050 (EC 2011). In 2010, EU issued a Directive (EC 2010) which requires that all new buildings within EU are to be "nearly zero-energy buildings" by 2020, and public buildings by 2018. These objectives are to be met through a number of measures aimed at improving energy efficiency, including promotion of energy-efficient and low carbon footprint materials; these developments are expected to increase the use of wood.

In 2006, the Government of the UK declared that all new residential buildings are to be zero carbon by 2016. In Canada, the Province of British Columbia introduced in 2009 an act that requires wood to be considered as the primary building material in public buildings. Many other provinces have introduced similar requirements thereafter.

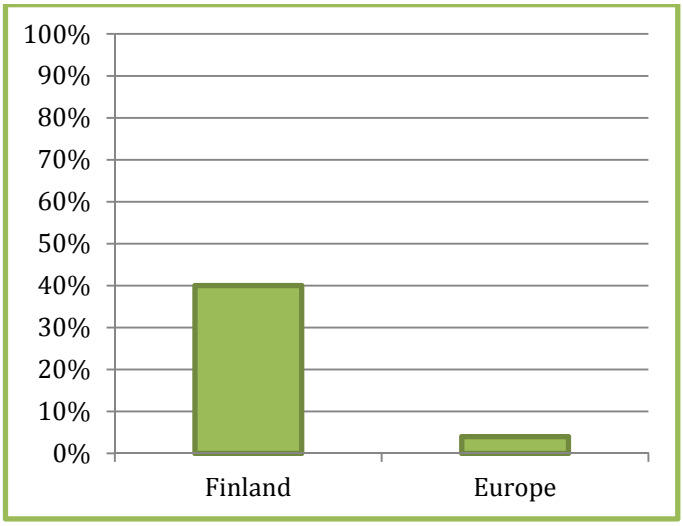
There are national and international certificates that allow classifying and comparing the environmental effects of buildings. They conduct the designing, construction and use of green buildings. Some examples are shown in the table below.

LEED	**BREAM**	**PromisE**
Leadership in Energy and Environmental Design (LEED) is an American certificate for green buildings, used internationally. It takes into account the ecological effects of a building throughout its life cycle, and has different rating systems for different types of buildings.	Building Research Establishment's Environmental Assessment Method (BREAM) is a British certificate. It gives the building a score, based on a comprehensive evaluation of its ecological effects. According to the amount of BREAM certificated buildings, it is the most used green building certification system.	Tool for categorizing the buildings based on their environmental effects. The criteria are human health, use of natural resources, ecological effects and control over environmental risks. The certificate is invented and used in Finland.

Source: Green Building Council Finland

The regulations and policies have an important influence to the state of wooden construction in different countries. There is significantly more experimentation and knowledge when the development has not been smothered by the strict regulations. The collaboration between the different operators - the companies, architects, researchers, politicians and universities - is also very important. In addition, industrial activity is necessary.

Figure 3 Share of Wood in Construction



Case: Part of the EU2020 Strategy:

"Climate change and energy sustainability"

- Reduce greenhouse gas emissions by 20% compared to 1990 levels
- Increase the share of renewables in final energy consumption to 20 %
- 20% increase in energy efficiency"

http://ec.europa.eu/eurostat/

Source: Puuinfo.fi

4.1 Europe

The traditions of wooden construction are strong especially in the area of the Alps and in Scandinavia, because of the vicinity of the forest resources. The small residential houses in these areas are mainly built with wood. The contemporary direction is towards increasing the use of wood in multi-storey houses and e.g. offices and agricultural buildings. Public buildings made out of wood are can also be seen in many European cities.

New technologies have shifted the construction traditions from cottage-like small houses to experimental and large-scale, modern buildings. The *Eurocodes* create the frames for construction regulations in Europe countries, but the specific codes are composed in each country.

Table 6 Construction development by market segments in EUROCONSTRUCT countries 2015-2017 y-o-y %

EUROCONSTRUCT Countries (EC-19)	2014	2015E	2016F	2017F
Total residential construction	1.4	1.7	2.0	2.4
Total non-residential construction	0.6	1.9	2.7	2.0
Total civil engineering	1.7	2.4	3.0	3.8
Total	**1.2**	**1.9**	**2.4**	**2.6**

Source: 79th Conference Euroconstruct

BY COUNTRIES:

Sweden Sweden is considered as a pioneer in the field of wooden multi-storey houses. The regulations have allowed the use of wood in large-scale constructions, thus the techniques and knowledge have had the possibility to develop. Gained experience and references are themselves a driving force in further development. Wooden multi-storey houses have approximately 20% market share, where over two thirds are built with modules. One important issue increasing the use of wood is the cost efficiency: a wooden multi-storey building is approximately 10% cheaper compared to concrete ones (Tolppanen et al. 2013; Haapio, A. 2013) The city of Växjö has had a strong vision of becoming a modern wood city: wooden multi-storey buildings and public buildings have been built since the 1990s. An intense collaboration between the city, business

sector and research field have together driving the development of sustainable wood construction (KESTI 2014).

The share of wooden bridges out of all new bridges is nearly 20%. There is a great level of knowledge in mechanical protection methods, as no creosotes are used in protecting the wooden bridge materials (Heinänen, L. 2014).

Norway Wood has been a traditional construction material. The development has been continual – importantly, the regulations have always allowed constructing wooden three-storey houses. Wood is a common material in public buildings as well, e.g. the art gallery building in Oslo by Renzo Piano. The annual share of wooden bridges out of new bridges is 10% (Heinänen, L. 2014). A modern example of wooden bridge is the Da Vinci Bridge in Ås, near Oslo.

Denmark Denmark is a country that has been globally known as a forerunner in design and trends, where sustainability is also taken into account. Compared to other Nordic countries, the construction tradition in Denmark has been based more on the Central European traditions, thus brick and stone buildings are the most common materials. However, the knowhow and interest towards wood construction is growing (*Traeinfo.dk; Puuinfo.fi*).

Austria Austria has a long tradition of wood-based construction, especially solid wood. Modern timber framed multi-storey houses with timeless façade design can be found in Austrian cities. The funding of the public constructions is linked to eco-efficiency. An Austrian company KLH produces cross-laminated timber by the German name *KLH,* and their products have been used in all types of buildings around Austria as well as abroad. Stora Enso's CLT production takes place in Austria (*Puuinfo.fi*).

Stora Enso has participated in wooden school projects, and so far five schools have been constructed in Austria recently. The schools made with prefabricated CLT modules are quick to build and pleasant for the pupils and teachersThe aim is to build more wooden schools in the future, and wooden buildings have growing demand also in general (*Storaenso.com*).

Switzerland Wood has strengthened its position in the field of multi-storey construction especially after the new, more permitting regulations since the end of the 1990s (Tolppanen et al. 2013). Wood is considered as a good construction material in city construction, and especially glulam products are used in multi-storey houses (P*uuinfo.fi*). As an example, a wooden school was constructed in 2012 to the city of Lausanne.

Germany Solid wood construction is typical in Germany. Germans have a long tradition in wood construction, especially in the Bavaria area. Timber-based construction has been increasing in recent years. The city of Wilhemsburg is an example of a German city where wood construction and new technologies have been examined and utilised (KESTI 2014). Another example of open-minded wood construction is the wooden spa, *Solemar*, in the city of Villingen-Schwenningen. However, as a bridge material the share of wood is as small as 0.04% (Heinänen, L. 2014).

Italy Lately, the use of wood in especially public constructions has been increasing, mainly because of the positive effects on environment. The communes and cities more often require research about the environmental effects. There are traditional wooden chalets especially in the area of the Alps.

France Wooden construction has had a significant part in small houses and school buildings. Also hall buildings and day care centres have been made out of wood, and nowadays the amount of wood used in multi-storey buildings is increasing. Wood construction materials have approximately 10% of all new dwellings per year (*Woodarchitecture.fi; gatewaybaltic.com*).

Spain Wood has traditionally been the material for smaller scale decoration constructing, such as doors and furniture, and the timber frame construction is still underdeveloped. The weather conditions are favourable to harmful insects, thus wooden construction materials need careful protection.

The city of Seville has introduced the possibilities of wood in a pioneer way. The Metropol Parasol shows how large, modern and unique structures can be made out of wood.

Great Britain

Wooden multi-storey buildings have become common in the Great Britain, especially in Scotland. Wood is treated in the same way as other construction materials in the codes and regulations, e.g. no sprinkler system is required. Wood has been used increasingly in social residential construction, small houses and public constructions, which have been driving forces in promoting the use of wood in other areas as well. In 2006, the Government of the UK declared that all new residential buildings are to be zero carbon by 2016, which is likely to increase demand for wood. Wooden construction has become somewhat a brand in the market sector. In addition, a national campaign, Wood for Good, was launched to promote the use of wood in all industries. Wood material is primarily imported from abroad. As a reference, one of the tallest wooden multi-storey houses in the world in located in London. The nine-storey residential building is made of CLT and was completed in 2009 (Tolppanen et al. 2013; *Puuinfo.fi*).

Russia

There has been fast growth in the use of wood in construction. Most of the timber consumed in Russia goes to construction sector (Marttila, J. 2010). Overall, the construction sector has been developing fast (Kärnä, V.) Significant growth in the need of energy efficient, ecologically constructed and affordable housing in the near future is estimated (Haapio, A. 2013). Russia is rich in wood resources, but the quality of the material is not considered as high as for example in Finnish wood products.

As a concrete example, the FIFA world cup will be held in Russia in 2018, and that will require lots of large-scale infrastructural constructions, which drives the growth of the construction sector in the next few years. Timber based constructions could be used as pioneer experiments in those construction projects.

4.2 North America

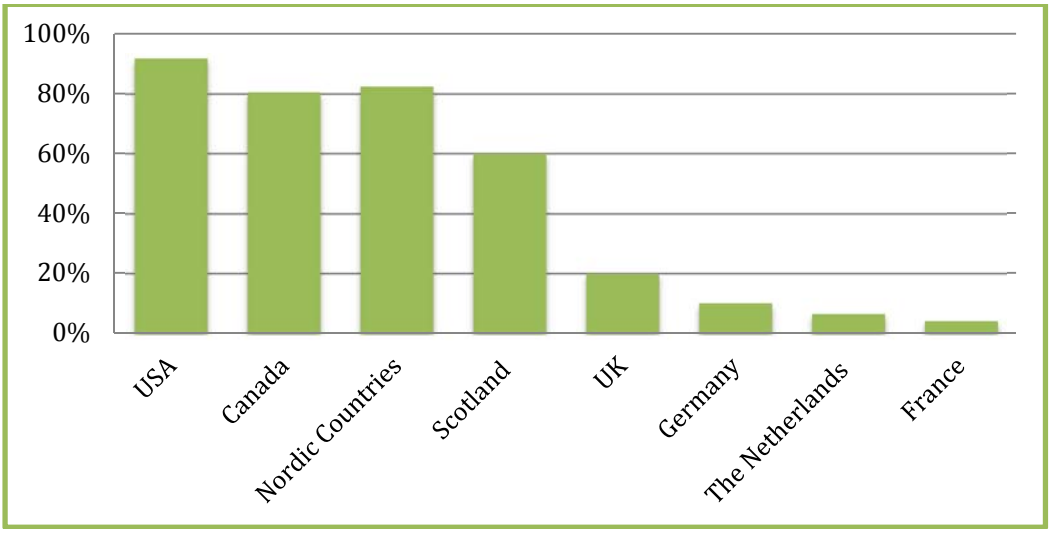
Wood has a long tradition as a construction material in residential buildings in Canada and in the United States. Especially in the West Coast, over 90% of the three to five-storey residential houses are made of wood.

The cost advantage compared to concrete construction is significant, approximately 20% (Tolppanen et al. 2013). Fire regulations vary state-specifically, but most commonly four to six-storey buildings need to have an automatic extinguishing system.

Canada is often considered as one of the leading countries in wooden construction. The political support to the use of wood is strong, as an example, the *Wood First Act* in British Columbia, which requires prioritizing wood as a construction material. It has increased the demand for wood in public constructions, as well as utilizing new construction technologies and marketing construction products (P*uuinfo.fi*).

In the United States (US), policies and programmes have been introduced to increase the use of wood in large-scale constructions, and promote of the advantages of wood overall. In 2014, a project was launched, which included a “USD 1 million competition for high-rise buildings built out of wood” and a funding of another USD 1 million for the education of wooden architecture. The future possibilities and growing trend of wooden construction are remarkable in the US (USDA 2014*; gizmondo.com*)**.**

Figure 4 **Share of Wood Construction in One and Two Family House Construction in Selected Countries or Regions**



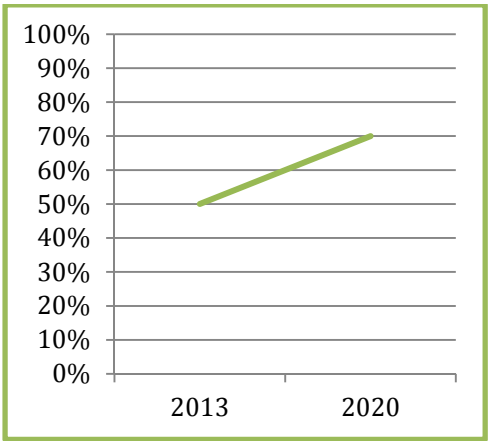
Source: Eriksson et al. 2009

4.3 China

China is one of the biggest constructors of the world: more than 30% of all the buildings are built in China, hence consuming over 50% of the cement globally (EUSME 2013). The continuous urbanization in China creates a large demand for infrastructural construction as well as housing including especially multi-storey houses. The rise of the standard of living in China is speeding up the demand for housing, with implications also on the demand for wood products.

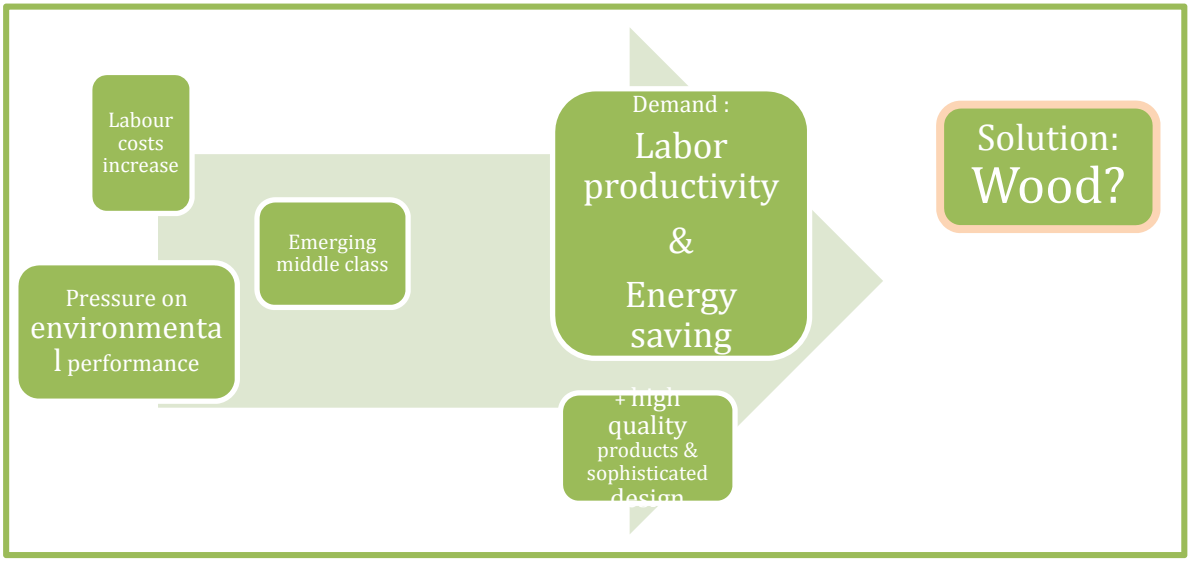
Environment is taken into account in the *Green housing* projects by the national authorities. The Chinese have been developing their own standards to replace the internationally used LEED standard. Among the people, the trend of being eco-friendly advocates the use of wood as a construction material, e.g. when the wealthiest people seek for unique houses and construction methods.

Figure 5 **Chinese Living in Urban Centres**



Source: EUSME 2013

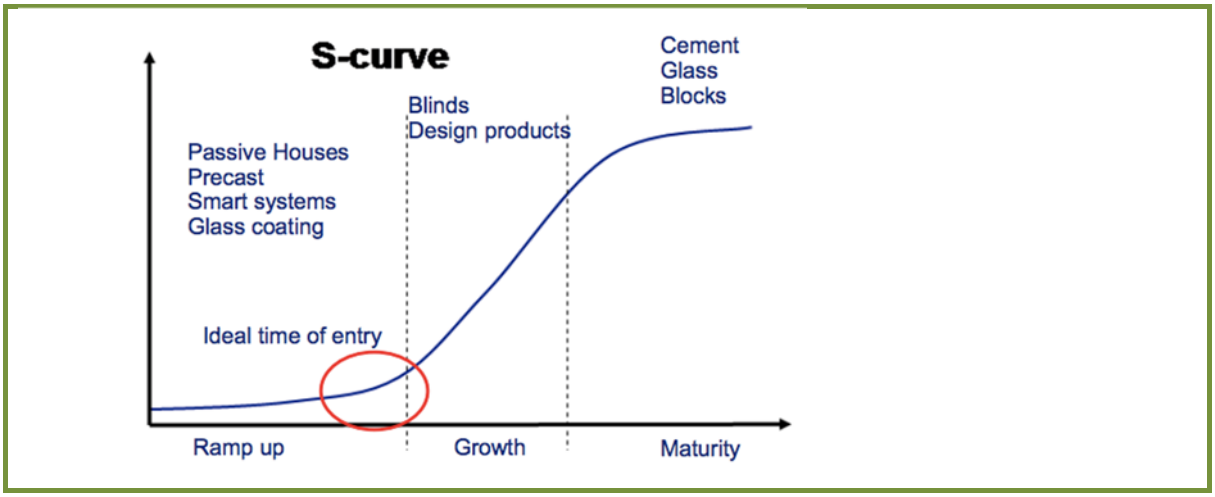
Figure 6 Chinese Society Changes



Source: EUSME 2013

China itself does not have sufficient amount of suitable forests and resources to use it in construction, thus it needs to import large amount of the material (Haapio, A. 2013; Aalto, N. 2012). The regulations have been quite strict towards all new construction materials and technologies entering the domestic markets (EUSME 2013). Wooden construction has been prohibited for long, as the risk of fire was considered to be a safety problem. Today, 25% of the consumed timber in China is used in construction, and the use of wood is increasing. The attitudes are becoming more open, which is seen also in the permissible new regulations. It is expected that public construction is driving the growing demand for wooden construction material (Svahnbäck, L. 2015). The "traditional" materials are still dominant, but new technologies, methods and materials entering the construction sector holds a lot of potential.

Figure 7 China's Construction Sector and the S-curve

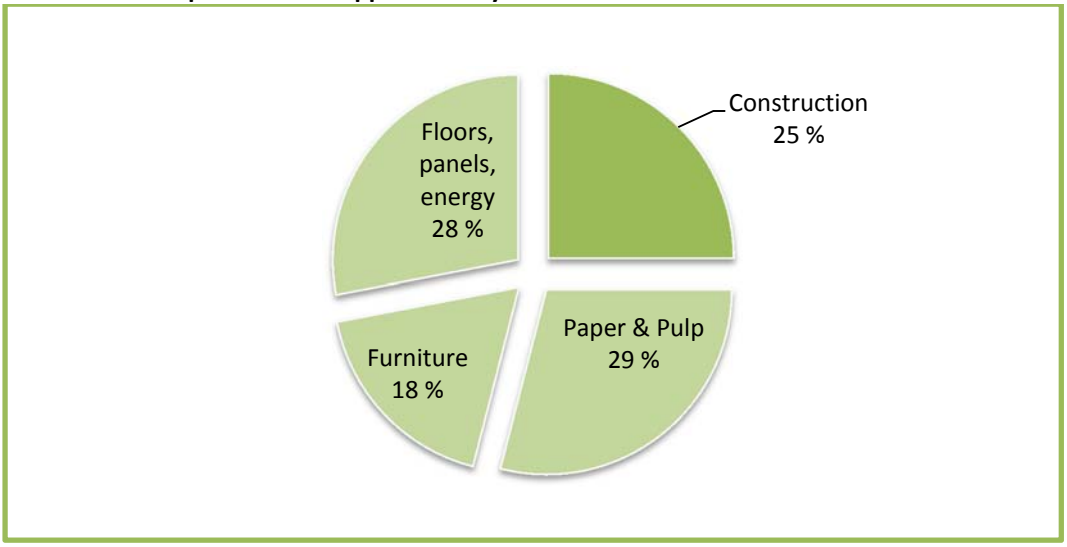


Source: EUSME 2013

While Canadian timber is exported to China and used as a material of buildings constructed by Chinese, Finnish log building, which has recently received growing interest, has a slightly different profile. The extent of value added is higher, and often the only process happening in China is the assembling.

Figure 8 Annual Wood Consumption in China

Domestic and Export - in total approximately 500 million m^3



Source: ***Svahnbäck, L. 2015***

5. WOOD-BASED ARCHITECTURE IN FINLAND

This chapter discusses the development of the state of wood as a construction material in Finland. The main factors and acts of promoting its use are introduced, as well as the main obstacles. In addition, the end of the chapter provides a prospect of what is to come.

5.1 Traditional Wood

Finland has a long history in timber and wood construction. It is an obvious consequence of the fact that three fourths of Finland's area are covered by forest (Tolppanen et al. 2013).

Historically, wood has been the most common material in construction throughout Finland. That can still be seen as old wooden churches, buildings and blocks of old wooden houses can be found throughout the country. Nevertheless, some of those are destroyed in fires over time when the fire safety was nowhere near today's system.

To mention a specific construction style, the tradition of log construction has always had significance in Finnish building history. Today, it is experiencing a new wave, as its positive effects on health are recognised (see Chapter 2).

5.2 Past and Present

Today, approximately 80% of the small residential houses and almost all of the cottages in Finland are constructed out of wood (Tolppanen et al. 2013). Thus, the significant potential of wooden construction is in the field of larger buildings and constructions, such as multi-storey, hall and office buildings (TEM 2014) as well as bridges.

The development of wooden multi-storey houses started in the beginning of the 1990's, when the environmental issues were taken more into account, and there was an aim to find new ways to use wood. Around the turn of millennium, about ten wooden multi-storey houses were built as experiment, and they received positive reactions. That led to a renewal of the fire safety regulations, which improved the possibilities of using wood in multi-storey buildings. (Tolppanen, J. et al. 2013)

After a short quiet period, the developing of wood-framed multi-storey building was re-taken in 2009. The Finnish National Wood Construction Program aims at reaching a 10% share in less than four years. The main driving forces then were positive references from Sweden as well as the interest of large forest production companies to develop the wooden construction systems. Since then, the development of wooden multi-storey buildings has been ascending.

Case: Nordic Wood Programme

In years 1993 to 2002 there was a specific program, Nordic Wood, to promote the use of Nordic wood and improve its competitiveness, especially in the construction sector. Finland was a participant along with other Nordic countries. The outcomes were positive: e.g. the program contributed to multi-storey construction, and at least 40 new wood-framed multi-storey buildings were built as a result. Generally, the program created a sustainable platform for the Nordic countries to continue developing the status of wood as a construction and building material.

Source: Nordic Industrial Fund, 2002

From the builder's perspective, when it comes to the construction of multi-storey houses, wood can still be seen as a risk compared to other materials. The strict regulation system supports that by requiring more from wood than from traditional materials. Wood has its traditional weaknesses in moisture and fire durability, and the problems caused by water and fire are considered as risks. However, the fear of fire is actually not quite relevant, as the contemporary techniques create fire safe wooden structures. Yet, the fire safety regulations are not equal, and that makes wood a more expensive material in higher than two flat buildings (Mikkola, M. 2015). Additionally, the attitude towards expensive renovation costs is somewhat negative (Haapio, A., 2013). In conclusion, when the aim is to achieve economic benefit, the traditional materials, such as concrete and steel, are often preferred instead of wood.

5.2.1 Governmental Support

However, the new Finnish government seeks to increase wooden construction. Improving the conditions happens by creating national construction standards, and removing the obstacles from wood as construction material, as well as increasing the research of the field (Finnish Government Programme, 2015).

The aim of the Finnish Bioeconomic Strategy (TEM 2014) promotes the increase of wood and other renewal bioproducts. Launched by the Ministry of Employment and the Economy in 2012, the Strategic Programme for the Finnish Forest Sector MSO promotes "the competitiveness and renewal in the forest sector. Pursuant to its goals, the MSO increases wood construction, the use of wood, exports in the sector, as well as new business activities in the bioeconomy sector" (TEM 2014).

The national wood program is a significant part of the project. The MSO considers wood construction to have great potential, and states e.g. that the goal is to make "wooden construction into a significant part of urban construction". The aim of the MSO program is to improve the state of wood as a construction material, and improve its competitiveness.

The national wood program leader Markku Karjalainen tells in the interview that the three out of four of the main concrete goals have been fulfilled. The market share of wooden multi-storey houses has decupled as planned, education has been improved through added education programs, and the brand of wooden construction has been shifted through an active global promotion program.

As already done in few steps earlier in the recent years, the regulations are going to be changed towards more allowing when it comes to wooden construction.

Other examples of structural support and promoting wood are Runko PES and the new act on public contracts. Runko PES is an industrial standardization made to improve wood element construction (*Puuinfo.fi*). The new act on public contracts is a result of the new EU directives, which influence the Finnish legislature so that the customer can take into account the life cycle impacts of the building. It comes into effect in 2016 (Maaseudun tulevaisuus, 20.5.2015).

In addition to the regulations and standards, media has also an important part in promoting wood and its possibilities in construction. The Finnish web site *Puuinfo.fi* provides large amount of information, including articles, data, examples etc. about wood as a construction material - and material overall. Media plays a significant role also in the spreading of environmental knowledge, which again promotes the use of wood,

because of all of its ecological advantages. Media influences the public opinion, which is an important factor in creating demand and interest of developing the technologies.

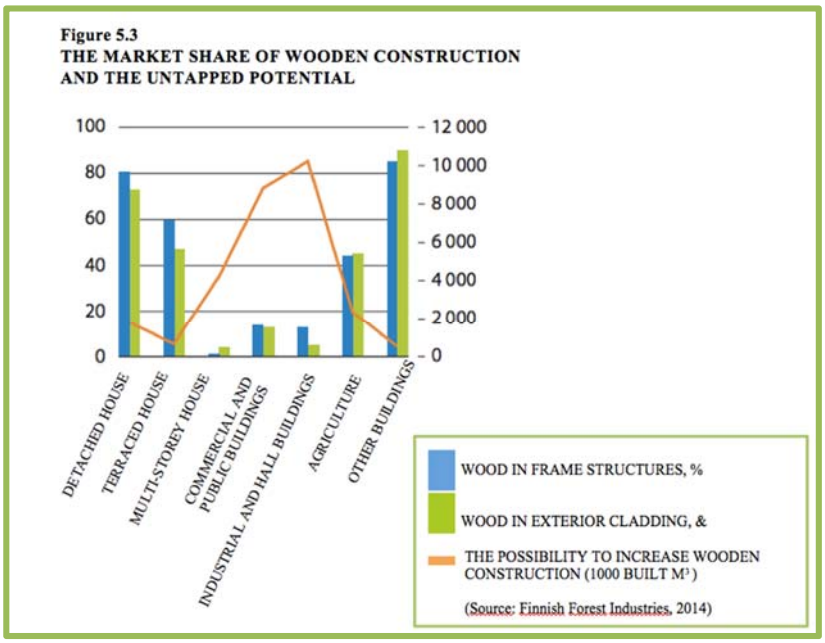
Ruiskumestarin Talo,
The oldest wooden building in Helsinki

*PuuEra i*n Heinola

5.3 Future

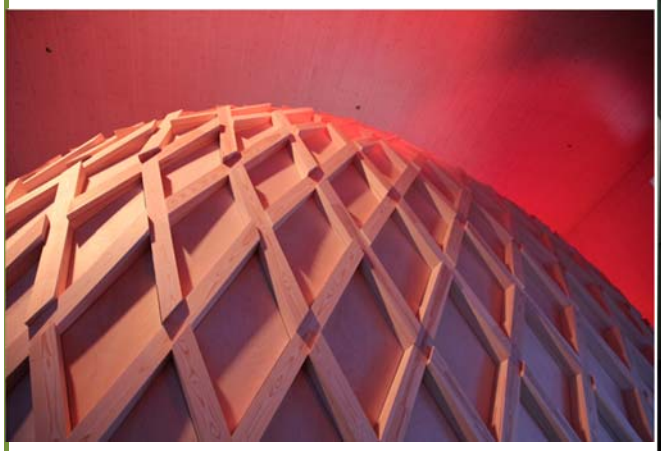
Wood is a very potential material, as discussed earlier in this paper. In the future, especially the environmental aspects are going to have increasing importance in all areas including construction - and that is why wood and its capacities need continuous research and developing.

Figure 9 Market Share of Wooden Construction and the Untapped Potential



Apart from the small residential houses, in which wood already is the most common construction material, increasing the amount of wood in construction requires references. Public constructions have an important part in making wood a more common and competitive material. Wood used in public constructions gives a supportive example to future projects, and private actors as well. Similarly, it creates demand on developing the know-how of wooden production and construction (Hietala J., et al. 2015). Thus, it increases capability and credibility of

wood – lack of which maintain the unattractiveness of wood as a construction material. Along the successful examples, the actual price and the possibilities of the construction become clear, which again increases the attractiveness of wood and makes it more compelling.



Case: ***The Duck Egg***

As his master's thesis, architect Markus Wikar realized an impressive wooden element to the Haltia nature centre in Espoo. The 1,200 original, CLT-pieces were produced completely by a robot, and assembled by hand at the site. The structure is situated in the main hall and serves as a special exhibition space for a work of art named *the Game Theory* by artist Osmo Rauhala.

Source: Haltia.fi

Universities have a central role in shaping the future of construction. There are specific programs of wooden construction, but there is still a long way from wood being the starting point and concrete only to be mentioned on the side. There should be more concentration towards large-scale wooden construction in the universities. Also long term research would be needed. Nevertheless, many architects are indeed open-minded towards new materials and are happy to work with wood in their projects. The structures in the education need some improvement: know-how and experience are necessary.

The confrontation between wood and other materials, mainly concrete, is a negative phenomenon. Ultimately, the rivalry is not beneficial to the continuous development of new construction technologies and materials. Collaboration between the industries would bare more fruit. It should be promoted that hybrid structures are reasonable alternatives as well; then the advantages of different materials would be exploited to the maximum.

Environmental issues have significant importance in increasing the use of wood in construction. The manufacturing of cement and steel causes 90% of the emissions out of all construction products in Finland (*Puuinfo.fi*). Because Finland is committed to various environmental agreements and sustainability principles, Finland has to change the construction methods and increase the use of renewal materials (see also Chapter 2.2).

Case: Zero-energy house	Case: GBC Finland
A house with yearly energy consumption of zero in total. These houses utilize renewal energy, e.g. solar power for electricity and bio based materials in heating. The energy efficiency directive requires that all new buildings have to be nearly zero-energy houses by the end of 2020. *Source: http://figbc.fi/tag/nollaenergiatalo/*	An example of actor promoting the ecological aspects in construction is Green Building Council Finland (GBC Finland). Their goal is to increase collaboration and connect procedures between the different operators of the field. They also provide an information bank as well as an updating education program, GBPro. *Source: http://figbc.fi/gbc-finland/*

5.3.1 Refurbishment

Especially in the future, renovating will be a significant field of construction and architecture. In 2013, more money was spent in repairing than in constructing new buildings (Pajakkala, P. 2014). In Finland, a large number of concrete element multi-storey houses built in the 1960s and 1970s will need renovation in the near future. Today, those houses have relatively low energy efficiency, which can be fixed effectively with wooden solutions, e.g. prefabricated elements (see Case: TES Energy Facade in Chapter 5.3.2).

Lightweight prefabricated wooden modular are optimal solution to additional flat construction. The facades can be renovated with wood, giving a whole new and modern appearance to “simple looking concrete cubes”.

It is somewhat problematic that a process such as adding a flat to a multi-storey house is complex in many ways. The decision-making is slow and has to happen between multiple actors, thus it is often seen as an unattractive project. That could be facilitated with regulations and policies. The number of people living in cities increases, thus it is necessary to make more apartments. Making cities more compact by expanding the existing buildings is one essential ways of developing.

All in all, wood has a great potential to be the material to use in different types of refurbishment construction processes – yet, that potential needs to be recognized and promoted.

5.3.2 Bridges

Wooden bridges are not as common here in Finland than in our Western neighbours. There is room to develop at that field, while wooden bridges cover only 4% of the all the bridges in Finland (Heinänen, L. 2014). In this report, Heinänen has studied the possibilities and challenges of wooden bridges in Finland. She states that when taken good care of, the wooden bridges are highly durable solutions. Wood is a beneficial material to be used in bridges because of the same reasons as in other constructions (see Chapter 2).

The challenge of using wood in bridge construction is though, the particular exposure to weather, especially moisture, which causes rotting (Heinänen, L. 2014). Protecting the wood by chemicals is ecologically problematic. On the other hand, other materials can be used to protect structures, as it is done in Sweden. The main factor slowing down the development of wooden bridges here in Finland is, according to Heinänen, the lack of competent knowledge, which then often leads to the problems during use.

Case: *TES Energy Facade*

TES (Timber Element System) Energy Facade, an international project (in years 2008 and 2009) promoting the use of prefabricated wood-based elements in energetic modernization projects. Concentrated especially in façade refurbishment of the existing buildings, the aim was to create a comprehensive system and method that could be used European-wide. Their pilot projects in Norway and Germany served as case studies and examples. The method enhances the thermal insulation and air-tightness, which makes the building energy efficient and more ecological and economic. The wood frame structure is self-supportive, thus a complete renewal of the architectural appearance of the old building: additional balconies, storeys or windows, new surface materials, etc.

Source: http://www.tesenergyfacade.com/index.php

Case: Nordic Timber Bridge Project

The bridges realized as a consequence of the Nordic Timber Bridge Project introduced the broad possibilities of wooden bridge construction. The technical reliability and innovativeness, as well as the aesthetical features were findings of the projects (Jutila, A. 2003).

Viikki pedestrian bridge

5.3.3 Export

Another future possible area to develop is the export market. Finland has great material resources, and high quality products. As the domestic demand and its growing potential is somewhat limited, it is important to seek for growth and possibilities from abroad. Areas where there is no specific tradition of wooden construction, e.g. Asia and Eastern Europe, are good potential markets.

In Russia, the share of timber construction in small residential house and three-storey buildings is augmenting. Finnish actors have a good reputation, and there could be increasing demand for Finnish knowledge, education and technologies in Russia. Additionally, the growing need for renovating buildings creates a market field for specified products and services worldwide (Haapio, A. 2013).

The Ministry of Employment and the Economy has also stated the aim of increasing the exporting of Finnish know-how and products in the field of wooden construction, especially concentrating on multi-storey houses. Also the potential of wooden bridges as export products is noticed (Heinänen, L. 2014).

Case: Estonia as Exporting Example

According to Markku Karjalainen (Development Manager in the National Wood Construction Company), an Estonian company, Kodumaja, has successfully created an exporting business of constructing wood framed multi-storey houses. In Estonia, the regulations concerning wooden multi-storey construction are still quite strict, thus they have seen the possibility of exporting the know-how and competitive business abroad.

Kodumaja has built multiple multi-storey buildings abroad, especially in Norway and other Scandinavian countries (95%). They use prefabricated space modules in the construction, which lowers the costs. The company works at the site together with local architects, who know their national construction codes and regulations. Estonian labour is relatively cheap, which is a great advantage for Kodumaja.

Source: www.kodumaja.ee/en

6. EXAMPLES OF WOODEN ARCHITECTURE

There are enormous amount of examples of wooden buildings around the world. All types from all phases of history to this day can be found: old cottages, churches and houses – and on the other hand modern wood architecture in eco-efficient houses as well as large-scale constructions. New techniques have widened the possibilities of wooden construction, and it could be said that outside the construction codes, today there are less limits than possibilities.

This chapter introduces examples of different types of wooden constructions, stressing the most recent projects and introducing some future ones as well. There are examples from Finland, but also a few references from abroad.

Case: Literature of timber architecture

Joseph Mayo's book *Solid Wood: Case Studies in Mass Timber Architecture, Technology and Design (2015)* presents a survey of new timber architecture around the world to reveal this construction type's unique appeal and potential". There is not too much literature about the use of wood in large-scale buildings, thus this book provides a wider perspective and a more comprehensive picture of the wooden construction and its possibilities. Especially when the use of wood is increasing in multi-storey buildings and commercial ones, this kind of book serves as a useful reference source.

Case: Finnish Wood architecture online

The website *www.woodarchitecture.fi* introduces multiple different examples of Finnish wooden architecture through beautiful pictures and a written description. The site, which is administrated by Finnish Timber Council (Puuinfo), offers all the basic information about the buildings and is available in many languages.

6.1 Puukuokka, Jyväskylä

Constructed in 2014, Puukuokka multi-storey house represents an extremely modern wooden architecture. It is made out of Stora Enso's CLT –elements, and rises up to eight floors high. The design is by architect Anssi Lassila from OPEAA Architects.

While entering the building, you are welcomed by the calm and comfortable atmosphere. The very first thing I notice about the interior atmosphere is the pleasant acoustics. "The house is basically noise-free", tells Jouni Liimatainen, a resident who participated in the process of constructing Puukuokka. Wood creates a very calm environment, where the amount of noise and echo is minimal. Also the positive effect of wood to control humidity can be felt, tells Liimatainen. In this building even the elevator shaft is wooden.

The architectonic appearance is modern and somewhat different from traditional multi-storey houses, which positive, as that promotes the innovative use of wood in construction. Wood does not create a cold bridge, which creates actually wider architectonic possibilities compared to concrete. In Puukuokka, that feature is benefited in the balcony construction: they project from the inner court wall and create a unique look.

Puukuokka has been a positive experience; there is going to be at least two more Puukuokka's next to the first one in the near future. The constructions are about to begin soon. In addition, right next to Puukuokka is located the church of Kuokkala, designed by the same architect. Although it has a stone façade, inside there is a beautiful wooden structure, made out of Finnish spruce.

6.2 PuuMera Kivistö, Vantaa

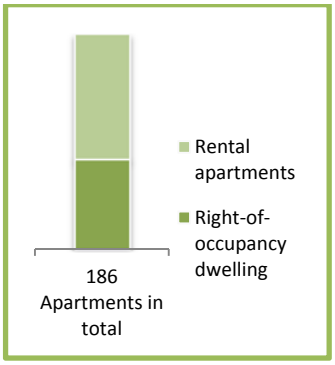
Considered to be the Europe's largest residential multi-storey building made of wood, PuuMera in Kivistö was completed to the Vantaa housing fair in July 2015. The wood used comes from Finnish woods. The residential area in total is approximately 10,100 m^2, and at its highest the building has seven floors. The first floor is concrete.

The building is a good example of an ecological wooden building: according to the calculations, the carbon footprint is less than a half of the average building. The low energy consumption is based on the chosen ecological materials and utilizing renewal energy. The prices of the apartments are ARA (The Housing Finance and Development Centre of Finland) Level, thus reasonably priced.

The building was constructed with prefabricated modules, which made the construction process fast: it reached the speed of one floor a week. The materials were manufactured in Finland. The wood material came from Pölkky Oy and Kuusamo Hirsitalot Oy produced the frameworks, while Koskisen Oy provided the façade modules and VVR Wood Oy from Heinola provided e.g. balcony and stair modules. Rakennusliike Reponen was the responsible construction company, and the design of building is done by Vuorelma Architects Oy.

Inside the building, wood is not largely visible, mainly because of the fire regulations. The walls in the apartments are cladded with plasterboard. Wood appears to the housing fair visitor differently depending on the apartment: some have more wooden surfaces than others. However, that is a choice of the interior designer. Wood is visible e.g. in the stairways and in the façade of the building (Rakennuslehti 26.6.2015).

Figure 10 Puumera Kivistö Apartments



MERA Construction is a concept created by Rakennusliike Reponen, and it means low energy construction. The examined and tested methods allow constructing buildings with only 70% energy consumption compared to corresponding traditional buildings.

6.3 Haltia the Finnish Nature Centre, Espoo

The Nature Centre is located in the middle of nature the Nuuksio national park in Espoo, Finland. Opened in 2013, the building is designed by Lahdelma & Mahlamäki architects. Beside the concrete ground floor, the structures as well as the cladding of the building are made of wood. As a public building constructed with Stora Enso's CLT material, Haltia is the first of its kind. Walls, roofs and floors are all made of CLT from Austria. The wood in the exterior cladding is impregnated with quartz sand. The new treatment is eco-friendly and fire safe.

One important goal of Haltia is to act as a pioneer building to show the possibilities of wood, thus to inspire the Finnish construction sector to increase the use of wood in large-scale constructions.

The building fits well to the landscape: it is designed to be smoothly in contact with the nature. Architect Rainer Mahlamäki has said in the interviews, that he has had a vision of the shape of a bird. The building sits steadily on the rock, and lookout tower is somewhat the long neck reaching the sky. The shape of the building is very organic, which shows that wood does not have to mean straight lines and boxes –the material does not limit the architecture.

From the visitors point of view the building is a great experience. The exterior is unique and interesting. Inside, wood creates a calm environment and brings the nature from the outside world to the interior. The scent of wood, the soft acoustics and the visually pleasant spaces make the visitor feel warm and comfortable. One feels welcomed and safe in Haltia. The restaurant in the upper floor has a large terrace for the customers to enjoy the beautiful view to the lakes and forests of Nuuksio while eating a delicious lunch (*haltia.fi*). (See also: *Case Duck Egg* in Chapter 5.3).

6.4 Other Examples of Different Types of Wood Buildings in Finland

Viikinmansio, 1997. Mauri Mäki-Marttunen Architects.

Heinolan PuuEra, 2011. Vuorelma Architects.

Café Birgitta, Hernesaari, Helsinki 2014. Talli Architecture and Design. A modern log building with a façade combined with charred wooden surface and large glass windows opening a sea view. Design by Architect SAFA (Finnish Association of Architects) Minna Lukander, and the logs provided by Honkarakenne.

FMO Tapiola, Espoo 2005. Helin & Co.

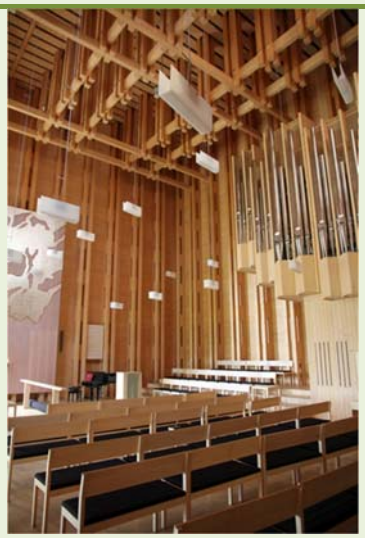
Lusto Finnish Forest Museum, Punkaharju 1994. Lahdelma & Mahlamäki.
Lusto is situated in the beautiful milieu in Eastern Finland. The building is mainly wood, in the tone of red, in its façade. The design of the building was chosen trough a competition, and the winner was Lahdelma & Mahlamäki's submission *Lusto,* where the name was also picked up.

Daycare Center Tillinmäki, Espoo 2012. A-Konsultit Architects

Kamppi Chapel, Helsinki 2012. K2S Architects.

Piano Pavilion, Lahti 2008. Wingårdh Arkitektkontor AB.

Säie Pavilion, Helsinki 2015. Aalto University Wood Program students.



Viikki Church, Helsinki 2005. JKMM Architects.

Kuokkala Church, Jyväskylä 2010. OOPEAA Architects.

Tillinmäki pedestrian bridge, Espoo.

Other sites:

- Viikki Wooden multi-storey houses, 2012. HMV Architects.
- Lintuviita 2, Seinäjoki 2013. Constructor Lakea Oy.
- DB Schencker Wooden Terminal Building, Vantaa 2013.
  The Viinikkala Terminal hall is built with Metsä Wood's Kerto material. It is one of the biggest terminal buildings in Finland; in total, the size of the building is 52 250 m^2.
- Pilke Science Centre and Metsähallitus Office, Rovaniemi 2010. APRT Architects.
- Sajos-Sámi Cultural Centre, Inari 2012. Architects m3.
- School extensions by Häkli Architects in Helsinki, 2000.
  - Munksnäs Lagstadieskolan
  - Tapanila elementary school
  - Maatulli elementary school
  - Malmi highschool
- Daycare centre Omenapuisto, Helsinki 2013. Häkli Architects.
- Vihantasalmi bridge, Mäntyharju 1999.

Table 7 Some Examples of Architects and Their Work Specialising on Wooden Construction

Office / Architect	Examples
Lahdelma & Mahlamäki	The Finnish Nature Centre Haltia, Lusto Finnish Forest Museum
ALA Architects	Helsinki Central Library
OOPEAA	Puukuokka; Kuokkala Church; Kärsämäki church
Häkli Architects	Daycare centre Omenapuisto; residential houses; school buildings
Anttinen Oiva Architects	Wood city
Vuorelma Architects	PuuMera Kivistö; PuuEra Heinola; Honkasuo wooden block
K2S Architects	Kamppi Chapel of Silence; Daycare centre *Salamanteri,*
Talli Architecture and design	Cafe Birgitta; Rakuunantie expansion (additional floor to a multi-storey building)
JKMM Architects	Viikki Church, Daycare Centre Leipuri
Artto Palo Rossi Tikka Architects	Pilke; Lahti Sibelius hall
Markus Wikar	Ducks Egg; wooden pavilions
Tuulikki Tanska	Master's thesis: *Methods of geometric optimization in architectural design Case: Sports Center in Linnanmaa, Oulu*. Received the Wuorio prize.

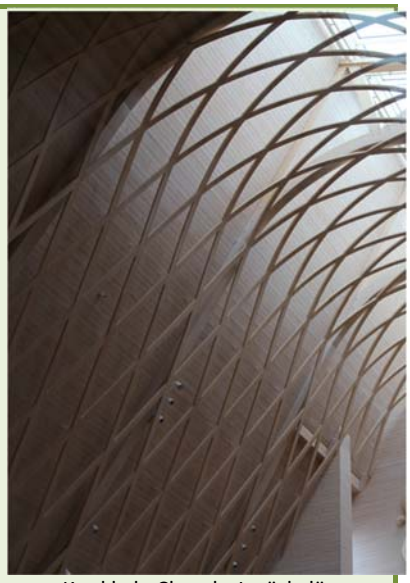
Wooden Structures in Lahti Sibelius Hall

Viikki Residential Buildings

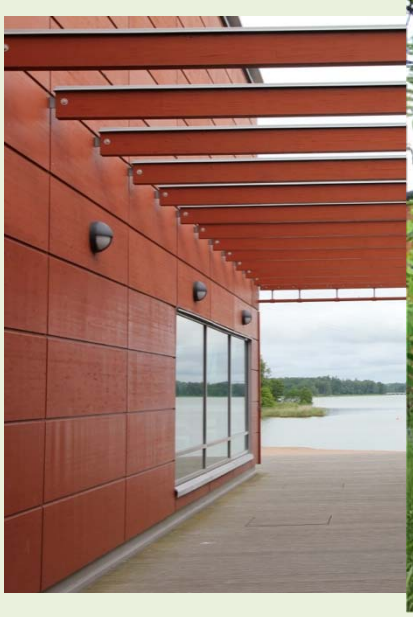
COR-Huset, Arabianranta

Lahti

Log Cottage, Vierumäki



Kuokkala Church, Jyväskylä



Hietaniemi Beach Pavilion, Helsinki

HOAS Residential Buildings, Kumpula

Vivola Residential Building, Vantaa

Lusto, Punkaharju

6.5 Examples Abroad

- **Metropol Parasol, Seville**

Completed in 2011, as one of the biggest wooden constructions in the world, Metropol parasol became a unique landmark for the city of Seville in southern Spain. The measures are enormous; length of the structure is 150 meters, width 75 meters and height 28 meters. The construction is designed by Jürgen Mayer H. Architects and built with Metsä Wood's Kerto Q panel. Altogether there are 3,400 unique wooden elements. The longest pieces are 16.5 meters.

The structure creates a shelter over the old town plaza of Seville. Different levels offer different things; on the ground floor there is an archaeological museum, on the street level there is a market hall, above that a lifted city square. The restaurant is situated on the third floor, and up in the fourth floor there is a scenic route open for the public. Metropol Parasol shows a great example of very courageous and unique wooden architecture. It serves the citizens as well as the tourists visually and with its services, and promotes the possibilities of wooden design to architects and constructors.

Source: jmayerh.de

- **Library at the dock, Melbourne, Australia**

Design by Clare Design and Hayball. The library building, opened in 2014, is the first public building in Australia that has been made with CLT. Altogether nearly 600m^2 of Stora Enso's CLT material has been used in the construction. The library is located by the sea in the Victoria Harbour, and represents a modern building visually as well as technologically. In addition, as a wooden building it has ecological benefits.


Source: storaenso.fi

- **Timber Tower, Hannover**

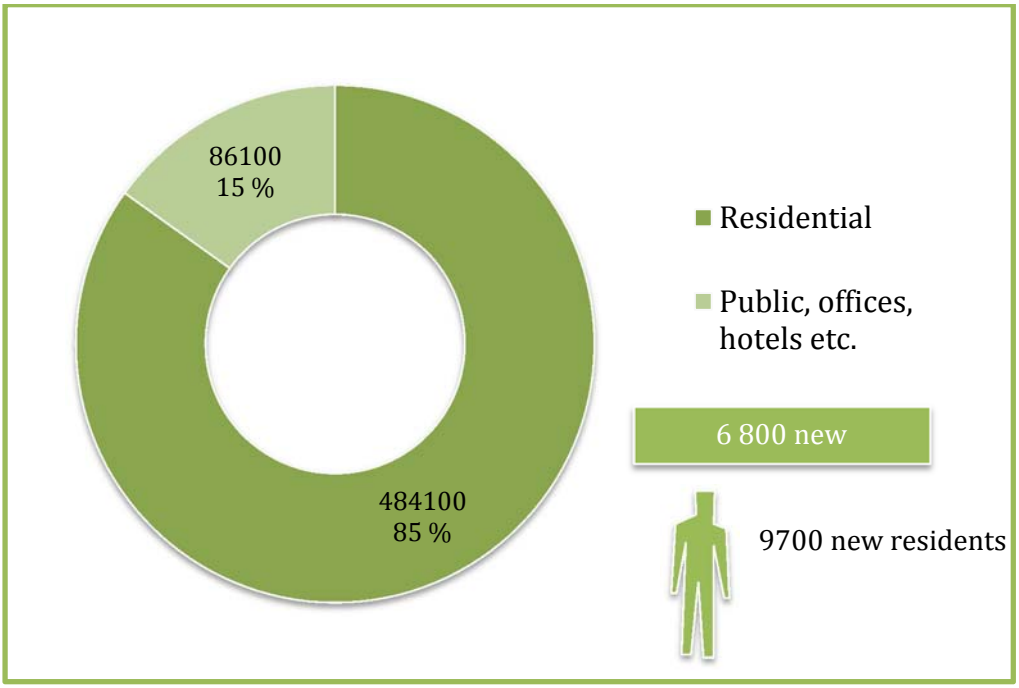
A 100 meters tall wind tower in Hannover is made with CLT. Construction was a relatively quick process, because of the preassembled components.

While wind energy is a green solution, the towers are usually constructed with steel, which is not an ecological material to produce. A wind tower made of wood is a "truly" green product, and becomes cheaper as well. The material is lighter to transport, and in the end of the estimated 20 years life cycle, the material can be recycled. (timbertower.de; cleantechnica.com)


6.6 Future: Upcoming Wooden Architecture

Puuinfo has listed the upcoming wooden multi-storey buildings in Finland. The list has 35 plans from different cities around Finland. The projects are mainly residential houses and sheltered accommodation or new wooden neighbourhoods. Some of those buildings will include offices, and the Wood City in Jätkäsaari will include a hotel. In addition, wood will have growing significance in hall buildings and other large-scale architecture.

Figure 11 New Wooden Multi-storey Buildings in Finland (storey-m^2)



Source: Puuinfo.fi

EXAMPLES:

Wood City

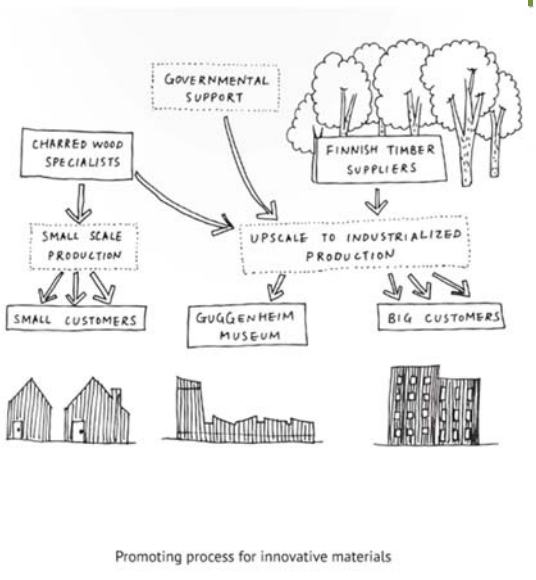
The construction work of a wooden quarter offering offices, hotel and homes in Jätkäsaari, Helsinki, is about to begin this year. The Wood City will be built with Stora Enso's CLT modules, which makes the construction process relatively fast and weather safe. The design of the wooden quarter is done by Anttinen Oiva Architects

Source: woodcity.fi

Guggenheim Helsinki

The architecture competition of Guggenheim Helsinki was resolved in June 2015. A Paris-based architect studio Moreau Kusunoki Architects won the competition with its submission *Art in the City*. If the project actualizes, it serves as a promotion to wooden construction: the main material of façade of is charred timber.

Source: designguggenheimhelsinki.org



Koli Cultura
A nature center planned to be constructed in the Koli National park. The center, in which wood is a main material, will offer cultural and nature experiences to tourists, taking the environmental aspects and sustainable development actively into account. The design is done by wooden architecture experts, JKMM architects and Harris-Kjisik architects.
Source: kolicultura.fi

OTHER UPCOMING:

- **Helsinki Central Library**, estimated to be complete in 2018. Finnish wood will be used in the façade as well as interior surface. The building permission was given on June 7th 2015; construction works are about to begin in fall. The design is by ALA Architects.

- **Löyly sauna and restaurant,** estimated to open in spring 2016. Located by the sea in Hernesaari, Helsinki *Löyly* will offer a traditional Finnish experiment in an urban and modern milieu for the tourists as well as the Finns themselves. The building is to be made out of wood, and wood will be the geometric façade as well.

- **Honkasuo neighbourhood, Helsinki,** a new neighbourhood is planned to be ready in 2020. The eco-efficient residential will include e.g. passive log homes and a wooden multi-storey quarter.

- **Linnanfältti, Turku**. Planned to be completed in 2020-2025. A modern residential district to central area, near the old castle of Turku. There will be wooden multi-storey houses two to five storeys tall. Among other goals, experimental wooden constructions as well as complementary construction in harmony with the existing area are considered important.

- **Käpy** (or *Cone*), **Kouvola**, a wooden multi-storey building, with two storeys reserved for offices and rest four for apartments. The city of Kouvola together with Kouvolan Asunnot Oy launched an architectural competition, and the winner was Häkli Architects / työyhteenliittymä 4M.

- **Matinkylä Daycare center *Salamander*, Espoo.** Designed by the K2S Architects and Landscape Architects Byman-Ruokonen. The building will have as much wood used as possible. The day-care center will be part of their "resident's common area" which will be completely renovated. The project is estimated to be ready around 2018.

7. CONCLUSIONS

According to the data analysed while doing this research, wood does have a growing importance in the construction sector. It has unquestionable advantages as a material, which has been proved by studies and experiences.

The environmental aspects will have a growing significance in the future, and the whole life cycle effects of buildings will be taken more into account in the construction codes and regulations. Wood has remarkably positive effects on environment compared to traditional construction materials, thus can be stated that the amount of wood used in constructions is to increase. In addition to the environmental benefits, the user experience has proved that the buildings are very comfortable to live and be in, and that the architectural possibilities are basically unlimited. Fire safety can be even better than in e.g. old concrete buildings.

The challenge in Finland is mainly the unattractiveness of using wood in multi-storey houses because of the fear of economical risks. Extra costs caused by regulations concerning only wood are part of the contemporary obstacles. The unfavourable attitude towards wooden construction reflects to lack of experience, which again slows down the development. The lack of knowledge creates uncertainty, and the risks appear maybe bigger than they actually are.

However, there is a tendency towards a positive development in wood construction. The global increase of wood in constructions creates a potential growing market for Finnish wood products and knowhow, yet it requires continuous developing and advancing.

Multiple acts in multiple fields are needed in order to increase the Finnish large-scale wood construction. Inspiring examples, development in education, technologies and research, as well as political support, are needed. Old prejudices have to shift, which can happen through active promotion, references and positive experiences. The more references the construction companies get, the lower the threshold of utilizing wood becomes. Opposite to special requirements, wood needs to be considered equally in the construction codes and regulations. These operations are mentioned e.g. in the National Wood construction Programme by the Ministry of Employment and the Economy, and the Finnish governmental program seeks to increase wood construction as well. For its part, the support of the state authorities inevitably affects positively on the use of wood in constructions.

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