DASOS CAPITAL

WOOD BUILDING AND REAL ESTATE IMPACT INVESTING

2nd edition I February 2021

MESSAGE FROM DASOS CAPITAL OY

Over the past years, the European market for wood-based construction has been growing with accelerating pace amounting currently to about EUR 5 billion per year. With the growth at some 8% per annum, the market is projected to exceed EUR 10 billion per year by 2030.

The above figures and strong trends concern primarily multi-storey buildings based on such modern materials as cross laminated timber (CLT) and laminated veneer lumber (LVL) as well as glulam. In addition to multi-storey buildings, there is also a large market regarding detached houses, and also infrastructure building using wood, and if all wood-frame buildings were to be counted, the resulting market volume would be in fact clearly larger.

It can be firmly concluded that the wood-based real estate segment is emerging as a substantial opportunity for real asset investment.

The market for wood-based (multi-storey) construction is evolving dynamically, especially in Germany (22% of the market; growth up to 13%/a), France (16%; <14%/a), UK (16%; <11%/a); Austria (12%; <11%/a). The actively developing Nordic construction sector (Finland, Norway, Sweden) forms a notable market with 16% market share and projected growth rates up to 15% for the coming years.

There are some key drivers in the market with expected long-term effects. First, it is essential to note that the trigger for the rapid development in the market has been in the technological breakthroughs of new engineered wood products (EWP), mostly CLT and LVL, which facilitate solid wood structures with strength comparable to steel and concrete and beyond.

Related to EWP, important steps have been taken for the associated building solutions. The technology of CLT and LVL construction features potential for particular efficiency gains resulting, for example, from modular solutions and reduction of tailor-made *in situ* work (i.e. reduced building time), and enhancing productivity with learning-by-doing. The competitiveness of wood-based construction is improving and a favourable cost-efficiency is expected.

Second, the versatility of the new engineered wood products aligns with flexible design and architecture with added value, replacing other construction materials in residential, office and public buildings as well as infrastructure uses (logistics, industrial and agricultural buildings). The design versatility includes also a scope for frontier energy systems, including solar (e.g. wall and roof structures) and geothermal solutions.

Third, wood is often perceived as a superior material by people living or working in wooden houses. The experience of a user, as well as several studies, refer to possible health benefits of wood, looking at both measured and perceived indoor environment quality. There is also evidence of human health and well-being benefits based on wood's biophilic properties.

Finally and vitally, wood-based construction represents an important instrument to improve the lowish climate change status of the construction sector, which accounted for 39% of global greenhouse gas (GHG) emissions in 2018.

Well-established research suggests that 1 m^3 of wood used in a building can store 0.9 tons of CO2 and substitute 1.1 tons of CO2, resulting in a total emission saving of 2 tons of CO2. As a rule of thumb, since 1 m^3 of CLT equals to 4 floorspace m^2, a 100 m^2 apartment equals to 50 tons saving in CO2, which corresponds e.g. to (offsetting) a carbon footprint of 30 return flights between London (UK)/New York (US).

With the rapidly evolving market of wood-based construction, a growing "urban stock for carbon" is being created. The accumulated wood material in all buildings in Finland currently equals to 84 million tCO2e with a growth of 23% over the period of 2000-2016. As a yardstick, the accumulated carbon in all buildings in Finland roughly equals to 70% (i.e. 700,000 ha) of the carbon stocked (on-soil) in all Irish forests – Ireland being one of the most dynamic forestry countries in Europe with active afforestation and doubled forest cover over the past 30 years. Furthermore, a recent research presents a scenario to storage an additional 420 million tons of CO_2 in European wooden buildings by 2040, i.e. more than three times the current CO_2 volume of all Irish forests.

Such an “urban carbon stock”, being maintained under roof in terms of house walls, floors and ceilings, may be considered a more permanent storage than a standing stock in a forest which is exposed to aging and risks related to insects, diseases, wind and fire. Thus, it should be attractive to store part of the atmospheric carbon captured by biological growth of forests into wooden buildings in the context of a sustainable climate-smart forestry and development of the low-carbon construction sector.

Regarding the world-wide investor community, there is an increasing global quest to invest in natural capital of which forests and wood are part of. In the context of ESG investing, an investment in wood-based construction matches particularly well with aims related to sustainability and societal impact.

In addition to the impact on climate change mitigation and environmental sustainability, the societal impact of wood-based construction is bound to increase in importance in future. Driven by urbanisation, the world’s building stock is expected to double by 2050. Within a wider framework of green building investment - including health and well-being perspectives - it is likely that wood will play a catalytic role when identifying hybrid construction solutions that incorporate various materials and technologies. Recyclability of wood will continue to form a critical benchmark when moving further towards circular bioeconomy.

In summary, the ongoing development of wood-based construction creates an attractive and expanding investment opportunity. Whilst the opportunity broadly maintains all well-established features of a real asset in terms of return and risk, there are also additional benefits of an impact investment type.

The acute interest by investors towards such benefits, coupled with definite technical parameters, do merit addressing the wood-based building as a specific real asset opportunity.

The first edition of this study was published by Dasos in 2015 (Review of Wood-Based Construction and Architecture – Technology, Status and Trends). Since 2015 the market for wood building in Europe has more than doubled. Fundamental development has taken place in environment, climate and energy policies, construction technology and products, and socio-economic trends which favour use of wood in construction. The current report represents a fully updated 2nd edition, and we hope that the study provides a fresh forward-looking overview of market drivers, technologies and prospects in the sector.

Helsinki, 5 February 2021

Olli Haltia, Dasos Capital Oy

Cover photos: *Top: Serlachius Art Museum Gösta Pavillon, photo by Mikko Auerniitty, Designer/Manufacturer MX_SI Architectural studio, Arkkitehtitoimisto Huttunen – Lipasti – Pakkanen Oy (puuinfo.fi)*
Bottom left: FMO Finnforest Modular Office, photo by Dasos/Nora Anttonen
Bottom right: Joensuun Pihapetäjä, Photo by Mikko Auerniitty, Designer/Manufacturer OOPEAA (puuinfo.fi)

IMPORTANT INFORMATION

DASOS CAPITAL OY

Dasos is an Investment Advisory and Fund Management Company located in Helsinki, Finland providing timberland investment advisory services to institutional investors, foundations, endowments, family offices and private equity clients. Dasos acts as an investment advisor for private equity funds specialised in sustainable timberland investments in Europe and emerging markets.

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ABBREVIATIONS AND ACRONYMS

BREEAM	Building Research Establishment Environmental Assessment Method
CLT	Cross-laminated timber
CORC	CO2 Removal Certificates
CO2	Carbon dioxide
CLT	Cross laminated timber
Dasos	Dasos Capital Oy
EC	European Commission
EDGE	Excellence in Design for Greater Efficiencies, developed by IFC
EFI	The European Forest Institute
ESG	Environmental, social and governance
EU	European Union
EUR	Euro
EWP	Engineered wood products
GDP	Gross Domestic Product
GRESB	The Global ESG Benchmark for Real Assets
GtCO2e	GtCO2e
GHG	Greenhouse gas
IEQ	Indoor environment quality
ICC	International Code Council
IFC	International Finance Corporation
LCA	Life-cycle assessment
LEED	Leadership in Energy and Environmental Design
LVL	Laminated veneer lumber
Mt	Megaton
MtCO2eq.	Units of metric tons of carbon dioxide equivalent
p.a.	Per annum
REIT	Real investment trust
RTS	The Building Information Foundation
SITRA	The Finnish Innovation Fund
SYKE	The Finnish Environment Institute
T	Ton
UK	The United Kingdom
UN	The United Nations
US	The United States
USA	The United States of America
USD	United States Dollar
VTT	Technical Research Centre of Finland
WBGC	The World Green Building Council
H_2O	Water vapor
CH_4	Methane
N_2O	NITROUS oxide
O_3	ozone

GLOSSARY

Carbon footprint — **T**otal greenhouse gas (GHG) emissions caused by an individual, event, organisation, service, or product, expressed as carbon dioxide equivalent.

Carbon sink — A carbon sink is anything that absorbs more carbon than it releases as carbon dioxide (CO_2).

Carbon store/stock — Quantity of carbon contained in a "pool", meaning a reservoir or system which has the capacity to accumulate or release carbon.

CO_2 emission — Carbon dioxide (CO_2) is a colourless, odourless and non-poisonous gas formed by of carbon and in the respiration of living organisms and is considered a greenhouse gas (GHG). Emissions means the release of GHG and/or their precursors into the atmosphere over a specified area and period.

CLT and LVL — Cross laminated timber (CLT) and Laminated veneer lumber (LVL) are high-strength solid engineered wood products that are used in structural applications. CLT and LVL products are made up of multiple layers of thin wood assembled with adhesives that ensure a high strength.

Embodied carbon — Carbon emissions associated with materials and construction processes throughout the whole lifecycle of a building or infrastructure. Embodied carbon includes material extraction, transport to manufacturer, manufacturing, transport to site, construction, use phase, maintenance, repair, replacement, refurbishment, deconstruction, transport to end of life facilities, processing, disposal (Green Building Council).

Green building — A building that, in its design, construction and operation, reduces or eliminates negative impacts, and can create positive impacts on the climate and natural environment throughout the building's life-cycle.

Greenhouse gas — A gas that absorbs and emits radiant energy within the thermal infrared range. Greenhouse gases (GHG) cause the greenhouse effect on planets. The primary GHG in earth's atmosphere are water vapor (H_2O), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and ozone (O_3).

Impact investing — Investments made into companies, organisations and funds with the intention to generate a measurable, beneficial social or environmental impact alongside a financial return.

LCA — Life-cycle analysis (LCA) is a systematic set of procedures for compiling and examining the inputs and outputs of materials and energy, and the associated environmental impacts directly attributable to a building, infrastructure, product or material throughout its lifecycle (ISO 14040: 2006).

Operational carbon — Emissions associated with energy used to operate a building or in the operation of infrastructure.

Wood construction — Refers to any form of construction in which the load-bearing structural frame is partly made from wood-based products.

1. GREEN BUILDING AND WOOD CONSTRUCTION

KEY MESSAGES

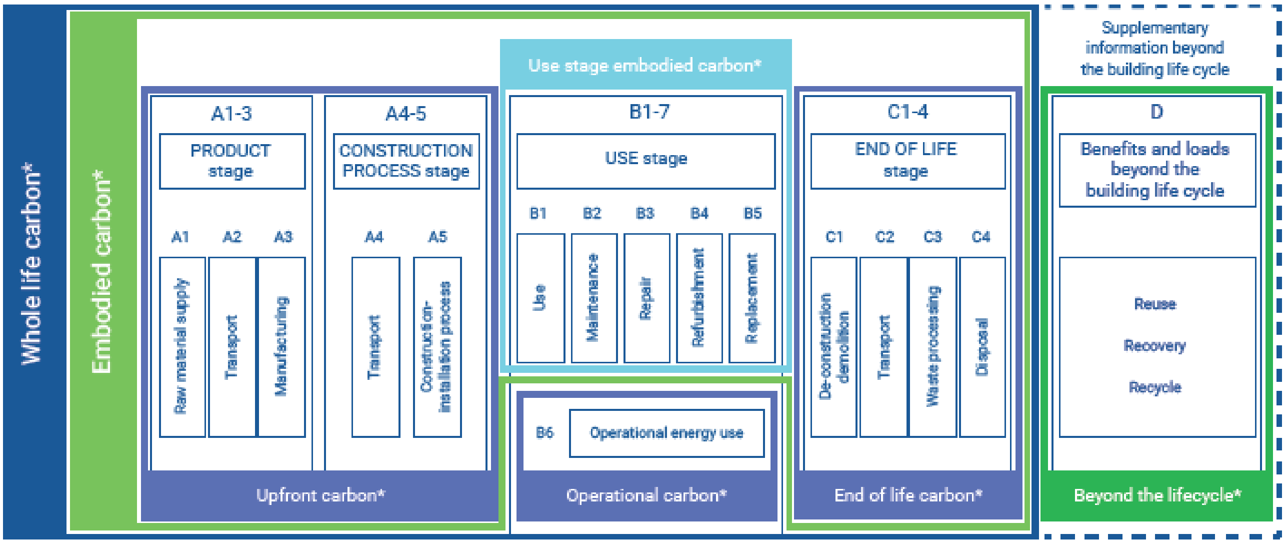
- *The global building and construction sector accounted for 36% of final energy use and 39% of energy- and process-related emissions in 2018.*
- *The sector has significant potential for delivering substantial and cost-effective greenhouse gas (GHG) emission reductions and mitigating against climate change.*
- *The construction of green buildings is driven by global initiatives and public private partnerships, the European (EU) policies and directives, and national low-carbon policies and programs.*
- *Wood building construction is part of the green building trend and plays an important role in decarbonising the construction sector in many countries, Finland and Sweden included.*

1.1 Environmental Impacts of the Construction Sector

Buildings are responsible for some 36% of the global final energy use and 39% of the global energy-related carbon dioxide (CO2) emissions and therefore have an important role in the shift towards a low-carbon economy consistent with the Paris Agreement targets. Concrete and steel production, in particular, are responsible for a large share of these global emissions. In 2018, the global buildings sector emissions increased for the second consecutive year, rising by 2% from 2017 to a record high of 9.7 GtCO2. In the USA, nearly 50% of total carbon emissions come from the building sector, largely from steel and concrete production. In the UK, the construction sector accounts for around 45% of emissions, and in Canada around 30% (Global Alliance for Buildings and Construction, International Energy Agency and the United Nations Environment Programme 2019; Leskinen *et al*. 2018).

The building sector's carbon emissions are released not only during the operational life but also during the manufacturing, transportation, construction, and end of life phases of all built assets (Figure 1). These emissions, commonly referred to as embodied carbon, have largely been overlooked historically although they contribute about 11% of all global energy-based carbon emissions whereas 28% comes from operational carbon. Carbon emissions released before the use of a building or an infrastructure starts - called upfront carbon - are estimated to be about half of the entire carbon footprint of new construction between now and 2050.

Figure 1 Concepts of Upfront, Embodied and Operational Carbon across Life-Cycle of a Building Assessment



Source: World Green Building Council (2019). Bringing embodied carbon upfront.

Construction sector and buildings have also other adverse environmental impacts beyond CO2 emissions, and they can be significant. In the EU, the construction sector is responsible for

- 36% of all CO2 emissions;
- 40% of total energy consumption; and
- 50% of all extracted materials (*https://ec.europa.eu/easme/en/news/sustainable-buildings-europe-s-climate-neutral-future*).

By 2050, the world's population will approach 10 billion, a 27% growth from today, with more and more people living in urban areas. As a result, the world's building stock (global floor area) is expected to double, exacerbating environmental impacts and the climate crisis through massive CO2 emissions (World Green Building Council 2020). The built environment presents a crucial opportunity to tackle the climate challenge; decarbonising the building sector is a cost-effective way to mitigate emissions and contribute to the Paris Agreement target of a global temperature rise this century below 2 degrees Celsius above pre-industrial levels.

Embodied carbon emissions are affected by many factors, including the volume of the structure installed, but especially, by the choice of materials and associated carbon intensity, energy use in their manufacturing, transport, construction, and maintenance efficiency, and finally how the materials are removed and treated at the end of life. Life-cycle analysis (LCA) is needed to compare the environmental and economic impacts of various construction materials such as wood, steel, and concrete for designing buildings which are decarbonised across their whole lifecycle.

Green Building Trends and Wood Construction

The choice of building materials, including wood, is only one of the means to impact the volume of embodied carbon, but it also influences the possibilities to reduce emissions from building operations and to create healthier, more comfortable, and productive spaces. Further, the net impact on carbon may be increased significantly through the substitution effect, i.e., increasing the use of wood as a substitute for more carbon emitting and energy intensive materials, such as steel and concrete. Wood is used in construction in diverse ways, both as principal building material and in combination with other materials, including concrete and steel.

Globally, the share of green building and wood construction of total new construction is still quite small, with a lot of variation between regions and countries and type of buildings. However, there has been increasing focus on the carbon footprint of buildings, which has been reflected in increasing investments in green buildings, including increasing use of wood in all buildings, and specifically in the construction of multi-storey residential buildings and public buildings (hospitals, schools, libraries, etc.) and infrastructure (e.g., bridges). These trends have been visible, especially in Sweden and other Nordic countries, but also in many other European countries (e.g., France, Germany, Austria, and the UK) and beyond in USA, Canada, and Japan, and more recently also in China.

This report describes and assesses these trends in more detail, specially focusing on the role of wood construction in addressing environmental concerns in general in Europe, and particularly in Finland (chapters 1.1, 3 and 4). Chapter 2 describes the benefits of wood as a construction material, different wood products and related technology. The final chapter provides an overview of investing in wood construction. Construction covers buildings and infra but this report focuses on buildings, and further on wood construction in high-rise buildings (residential, offices) which in most countries offers the largest opportunities to increase wood construction and thereby address climate concerns.

1.2 Expanding Green Building and Wood Construction: Push towards Decarbonisation

EU and National Policies and Regulations Drive Green Construction

The rapid expansion of building construction and the need to reduce emissions present a massive investment opportunity in the "green building sector". However, green buildings still comprise a relatively small share of global construction. In 2017, global total investments in green buildings accounted for about 8.5% (USD 423 billion) of the estimated total USD 5 trillion, including renovation. However, the global green building market is expected to grow annually at an average rate of over 10% percent until 2030 while building construction in general is projected to increase by 4.5% annually in the coming years, i.e., the relative share of green building construction of total building construction is projected to more than double (*https://www.worldgbc.org/news-media/2018-global-status-report-towards-zero-emission-efficient-and-resilient-buildings-and*).

The expansion of green building markets, including increasing use of wood as a construction material, is driven by the global, regional, and national climate and broader environmental concerns and related policies, laws, and more flexible building and fire codes. The development of new construction materials and technology have also stimulated green building.

The EU has a long-term Roadmap 2050 for a competitive, low-carbon economy to cut GHG emissions by 80-95% of the 1990 levels by 2050 to keep climate change below 2°C. This sets highly ambitious targets for reducing GHG emissions from residential buildings by about 50% by 2030 and 90% by 2050 (EC 2011). The EU Energy Performance of Buildings Directive (2010) requires all new buildings to be “nearly zero-energy”. This Directive also introduced an energy performance label for buildings, ranking them from “A” to “G,” with “A” being the most energy efficient. As of 2018, the Energy Efficiency Directive and the Energy Performance of Buildings Directive include a non-binding target to improve energy efficiency by 32.5% by 2030. The Energy Performance of Buildings Directive requires member states to develop long-term strategies to fully decarbonise and reduce the energy use of their entire building stock.

These policy developments, together with national low-carbon construction plans/programs/targets, and some other developments, are boosting “green housing” and wood construction development. In early 2020, the European Parliament adopted the European Green Deal. It “encourages the promotion of timber construction and ecological building materials” and the use of sustainably sourced renewable materials in the transition to a climate-neutral economy. It also highlights the need to stimulate investments in the development of a sustainable bioeconomy in which fossil-intensive materials are replaced with renewable and bio-based materials in, for example, buildings, textiles, chemical products, packaging, shipbuilding, and, where sustainability can be assured, energy production”.

In 2019, the European Council adopted amendments to the Energy Performance of Buildings Directive (Directive 2010/31/EU) as part of the Clean Energy package. The following two amendments are important for developing green buildings: Long-term Renovation Strategy and New Buildings. The former requires EU member countries to establish a long-term strategy to support the renovation of national stocks of residential and non-residential buildings into highly energy-efficient and decarbonised building stocks by 2050.

The New Buildings section requires EU member countries to take necessary measures to ensure that new buildings meet minimum energy performance and environmental requirements. Many countries have developed roadmaps for low-carbon construction; e.g., the Finnish Ministry of Environment introduced its roadmap in 2017. Further, Finland, France and Sweden are considering approaches for allocating GHG ‘budgets’ and environmental benchmarks for the construction sector and buildings.

These policy changes are leading to adjustment of national building and safety standards and fire codes, as well as requirements to use LCA to assess environmental impacts. They are coupled with development of new technology and industrialized production systems and capacity which are making the construction of wood buildings in Europe more competitive. In Finland for example, the fire code was modified in 2011 to enable the construction of multi-storey wood buildings up to eight floors, and in 2018 the code was again modified allowing construction up to 18 floors. In addition, building codes in many European countries increasingly incorporate engineered wood products.

The International Code Council (ICC) has approved changes to the tall mass timber code following a multiyear effort by the ICC Ad Hoc Committee on Tall Wood Buildings formed in 2016. After years of study and testing, the code will allow construction with mass timber materials, such as cross-laminated timber (CLT), for buildings up to 82.3 m and 18 stories (WoodWorks - Wood Products Council 2019). The changes will take effect with the 2021 version of the ICC building code but some countries and states in the United States have already embraced the new “tall wood building code”. The International Green Construction Code issued in 2018 favours sustainably produced wood as construction material.

Private Sector Initiatives and Public Private Partnerships Are Pushing for Decarbonising Construction and Buildings

There are major global partnerships and initiatives for mitigating GHG impacts from the building sector, involving United Nation's (UN) agencies, the private sector and various associations, The Global Alliance for Buildings and Construction works towards zero-emission, efficient and resilient buildings, and construction sector through raising ambitions to meet the Paris Agreement goals and helping mobilize all actors along the construction value chain. With over 130 members, including 29 countries, it is the leading global platform for governments, the private sector, civil society, and intergovernmental and international organisations to increase action towards its objectives.

The World Green Building Council (WGBC) partnership involves some 80 National Green Building Councils, regional networks and private companies. The European network is a community of 23 national Green Building Councils, eight Regional Partners, and more than 4,500 member companies, including, for example, Stora Enso and Skanska. Low-carbon construction is also supported by the introduction of advisory services and tools by the national Green Building Councils. The WGBC is calling on the signatories of the Advancing Net Zero agenda - comprising businesses, cities, states, regions, and organisations - to take immediate climate action to reach net zero operating emissions in all new buildings by 2030; by 2050 all buildings should be 'net zero-carbon'. This is complemented by the Zero Carbon Buildings for All Initiative, which also calls for national and local leaders to drive decarbonisation of all new buildings by 2030 and all existing buildings by 2050. Low-carbon construction is also supported by the introduction of advisory services and tools by the national Green Building Councils.

Public-private partnerships have also emerged at local levels. In Finland, the Pirkanmaa Regional Association, municipalities, educational institutions, construction and wood industry companies, and the Finnish Forest Center, have launched a program to increase the share of wood multi-storey construction to 10% of all new construction and to 100% in renovations to add floors.

Wood Building Construction Can Play an Important Role in Decarbonising the Construction Sector

In synopsis, the global, regional, and national public and private sector initiatives and partnerships mean that all new buildings in Europe should be designed as low or zero-energy and carbon-efficient buildings in the near future. This will influence all construction, irrespective of main construction material; for example, work is already being done to reduce the carbon footprint of concrete and steel.

Due to the unique combination of renewability and biogenic origin, wooden products and related construction processes and technologies can provide significant opportunities to reduce CO2 emissions, or in fact, store carbon, and improve energy efficiency across the life-cycle starting from sustainable production of wood for processing. At the end of their service life, wood products can in most cases be recycled, thus extending the carbon storage effect, and/or be used as a carbon neutral fuel in cascade use, substituting for fossil fuels. In this way, using wood in construction supports the move towards a circular economy.

Globally, the public (national and local) authorities increasingly acknowledge that the building construction sector has significant potential over the short and long term to reduce emissions of CO2 by using materials with a low or zero-carbon impact and through energy-efficient structures, and that wood plays an important role in this. As a result, many countries have introduced national wood building programs and/or public procurement regulations (e.g., Finland, Sweden France, Canada, Japan, and New Zealand) to promote the use of wood in construction.

2. BENEFITS OF WOOD CONSTRUCTION

KEY MESSAGES

- *Wood buildings produce less GHG emissions, air and water pollution, solid waste and consume less energy resources than other construction materials according to many LCA studies.*
- *A net reduction of carbon emissions can be obtained by increasing the proportion of wood-based materials used in building construction.*
- *Wood and new products, such as CLT and LVL, are very versatile enhancing flexibility in the design of buildings and replacing other construction materials in residential, office and public buildings as well as in infrastructure uses, such as bridges and industrial and agricultural buildings.*
- *The combined effect of carbon storage and substitution means that 1 m^3 of wood used in a building can store 0.9 tons of CO2 and substitute 1.1 ton of CO2, resulting in a total emission saving of 2 tons of CO2.*
- *The wood accumulated in buildings represents an important and safe carbon storage. There is potential to increase wood construction in the EU by 2030 so that the accumulated net carbon storage in the European building sector would represent about 9.5% of the annual harvest.*
- *Substituting conventional building materials with wood in half of new urban construction could provide 9% of global emissions reduction needed to meet 2030 targets for keeping global warming below 1.5 °C.*

2.1 Environmental Impacts Across Life-Cycle Favour Wood

Wood has a lower environmental impact than alternative products, such as concrete or steel. LCA studies have shown that wood buildings produce less GHG emissions, air and water pollution, and solid waste, and they consume less natural resources than other construction materials. The benefits of using wood as a building material are discussed in more detail in chapters 2.2-2.5.

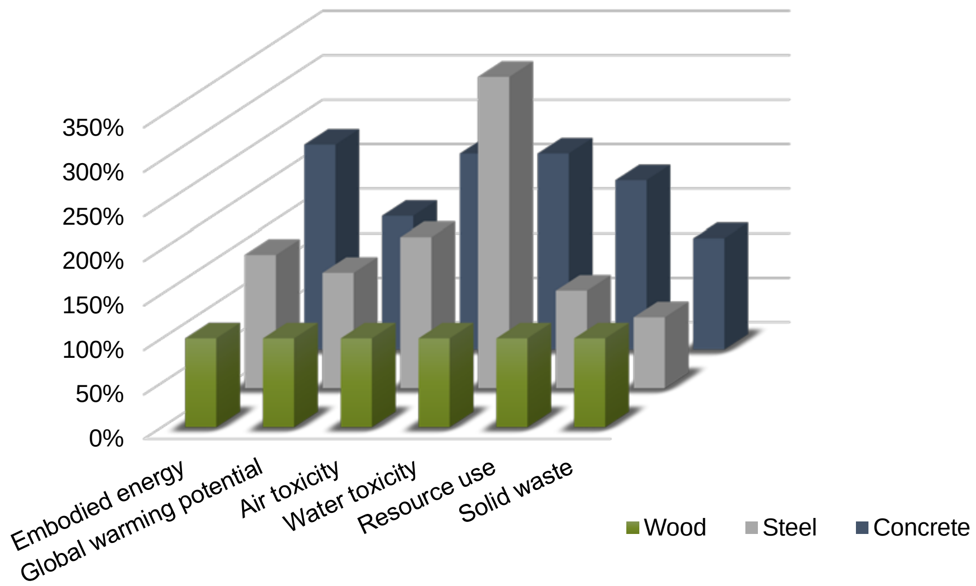
- *Wood is the only major building material that is both renewable and stores carbon*; carbon remains embodied in wood buildings and furniture throughout their service life.
- *Wood buildings emit less GHGs across the life-cycle relative to other structural building products* according to LCA studies.
- *Wooden structures improve energy efficiency through being an excellent insulator*.
- *Versatility of use*; *Wood can replace other construction materials* in many structures while providing the same functionality.
- The technical features of wood and wood-based products, such as CLT and LVL and related prefabricated components and modules, allow flexibility in design and construction.
- *Speed of construction time is enhanced* using prefabricated structures and modules which reduces construction costs and creates speed-to-market advantages.

Wood came on the top in the study ‘Environmental Profiles of Building Materials, Components and Buildings’ - one of the first substantive studies on the LCA of building materials undertaken by a major independent research body, the Building Research Establishment in 2015. Wood also scored highly in the 13 environmental impacts studied - from climate change to air and water pollution, and waste disposal. The Canadian Wood Council assessed environmental impacts of housing by type of frame (wood, steel and concrete) applying LCA and came up with similar results (Figure 2).

A study by Atsushi Takano at Aalto University shows that out of six materials, a timber framed building is the most material efficient alternative in terms of renewable and non-renewable materials per m^2, followed by light-gauge steel frame while concrete being clearly most inefficient.

When the carbon stored in wood products is included, sawnwood has negative net emissions. The combined effect of carbon storage and substitution means that 1 m^3 of wood stores about 0.9 tons of CO2 and substitutes on average 1.1 ton of CO2, resulting in a total saving of 2 tons of CO2.

Figure 2 Environmental Impacts of Housing Types (by frame) Based on Life-Cycle Assessment



Environmental impact relative to a typical wood-frame home (the 100% baseline) is shown for an equivalent house in light-gauge steel and an insulated concrete form. Data addresses the life-cycle portion from resource extraction through construction and does not include environmental impacts of building occupancy and demolition.

Source: Canadian Wood Council

The role wood will play in the low-carbon building transformation process will not depend only on the "green features" of wood and its technical characteristics as a construction material but also on changing perceptions of residents, designers, architects and especially large-scale construction sector, and pace of research and development in both construction materials and building construction technology.

2.2 Low and Zero-Carbon Construction

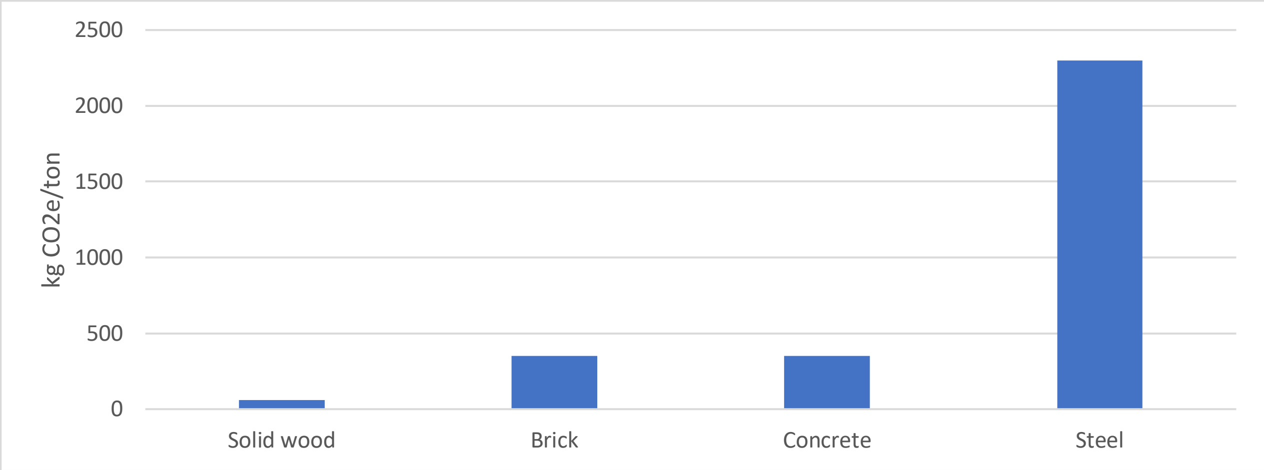
The use of wood-based construction materials reduces net CO2 emission in several ways: less energy is used in manufacture of the product and carbon is embodied in wood buildings or other buildings making use of wood material and substituting wood for more carbon emitting construction materials. Impacts of wood construction include:

- *A lower 'carbon footprint'*, meaning the lower quantity of GHG emissions during a product's manufacturing, operations, and disposal relative to other materials.
- *The "carbon stock/storage" effect* that refers to the fact that carbon remains embodied in wood buildings and furniture throughout their service life; 1 m^3 wood stores about 0.9-1 ton CO2.
- *Substitution effect.* The carbon impacts of substitution depend on the type of wood products used and what is substituted. The substitution factor, measured in kg C / kg C wood product) is 1.3 in structural construction (e.g., internal, or external wall, wood-frame, beam) and 1.6 in non-structural construction (e.g., window, door, ceiling and floor cover, cladding) (Leskinen *et al.* 2018).

Wood-framed building materials use less energy and emit less CO2 to the atmosphere over their life-cycle than materials for concrete-framed construction. Wood building components store carbon in all buildings regardless of their frame, insulation, and cladding materials. The largest potential for storing carbon can be achieved in external walls, intermediate floors and roof structures in which the service life is long.

Less fossil energy is needed to manufacture wood products compared to non-wood materials (Figure 3). According to scientific studies, the production of concrete elements causes up to ten times higher CO2 emissions compared to the sawnwood, glue-laminated beams and other solid wood products. In the case of steel, the difference is much more radical.

Figure 3 Carbon Footprint of Production of Various Construction Materials

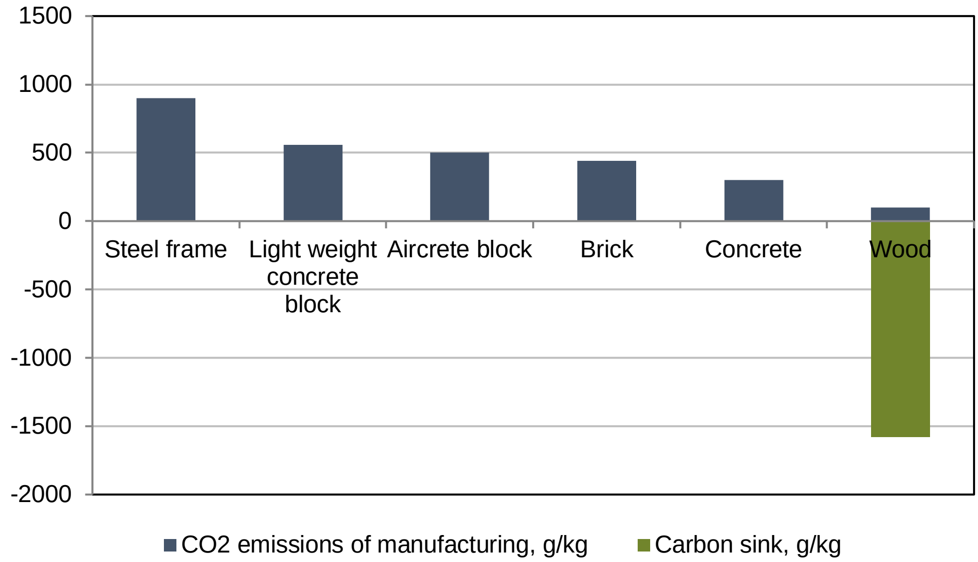


Source: SCA

A detailed LCA analysis by Rakennusliike Reponen Oy of four similar 5-storey apartment blocks in Kuninkaantammi Helsinki, two in wood, and two with concrete, found that the CO2 emissions of construction materials were 20% less in wood buildings.

When substitution effect by wood for higher carbon intensity materials is considered, the carbon storing capacity of wood makes it superior. A net reduction of CO2 emission can be obtained by increasing the proportion of wood-based materials in building construction, relative to other construction materials (Figure 4). However, often wood and concrete, or steel, need to be used in parallel; they do not always compete against each other.

Figure 4 Carbon Footprint of Various Construction Materials, Including Stored Carbon



Source: Based on Viljakainen 2009

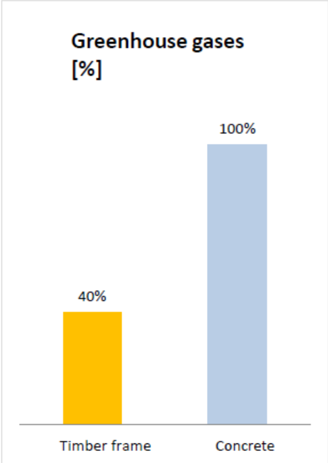
The carbon saving effect can be substantial as demonstrated by international examples in three countries (Box 1).

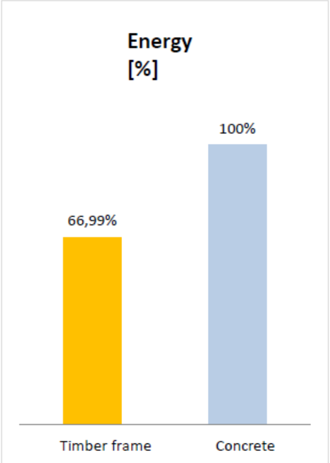
In the Netherlands, increasing the building stock with wood-frame houses could alleviate 10% of the total CO2 emission produced by the building sector, and in a scenario with maximum wood use (including all window frames, doors, roof structures, cladding, etc.) the savings could amount up to 42%.

Box 1 Examples of Carbon and Energy Savings in Wood Construction

Metla Research Centre, Joensuu, Finland

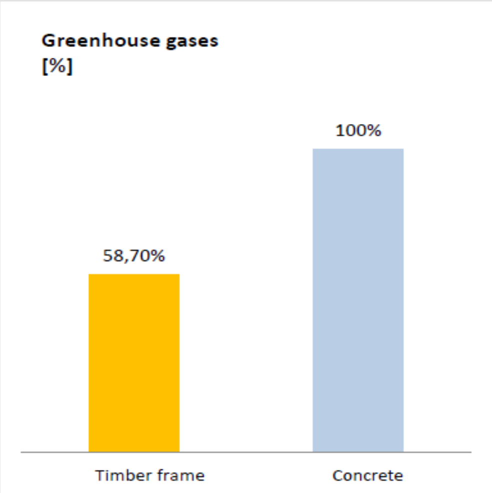
Photo: htpp://5osa.com





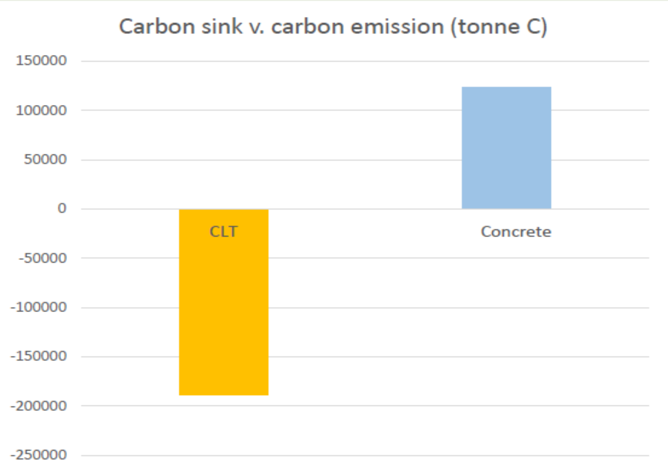
Wooden apartment block Wälludden Växjö, Sweden

Photo: Svenskt Trä



Apartment block Murray Grove, London; UK

Photo: buildingproducts.co.uk



Source: Kuittinen 2014.

The wood accumulated in buildings represents an important and safe carbon storage. According to a meta-analysis by Himes and Busby (2020) substituting conventional building materials with wood in half of new urban construction could provide 9% of global emissions reduction needed to meet 2030 targets for keeping global warming below 1.5 °C.

The 2017 scenario analysis by Hildebrandt *et al.* identified an achievable *potential* for accumulated net carbon storage of about 46 million tCO_2e per year by 2030 in the European building sector. This would represent about 9.5% of the annual harvest in the EU, meaning that in about ten years accumulated net carbon storage would equal one year's total harvest. Amiri *et al.* (2020) identified a potential scenario where carbon storage in wood buildings would reach 55 million tCO_2e per year by 2040, equalling 47% of the annual CO_2 emissions from the cement industry in Europe.

According to the VTT (Technical Research Centre of Finland), the accumulated wood material in all buildings in Finland amounts to about 46 million tons equalling 84 million tCO_2e (Vares *et al*. 2017). This carbon stock can be enhanced while reducing emissions from construction by using more wood in new construction by substituting for cement and steel.

The analysis, carried out by the Finnish consulting company Granlund Oy in 2020, suggests CO_2 net savings for *new* buildings in Finland by 2035 of 7-11% for all buildings, 13-20% for multi-storey residential buildings, and 10-17% for multi-storey office and commercial buildings. In the base scenario, the increase in the accumulated carbon stock in the built environment would be 40% higher by 2035 compared to the increase based on the current material shares in new construction.

2.3 Wood in Energy Efficient Construction

The increasing importance of energy efficiency and the mandatory energy efficiency requirements favour wood-frame buildings. Using wood helps save energy over the life of a building, as its cellular structure provides outstanding thermal insulation: 15 times better than concrete, 400 times better than steel and 1 770 times better than aluminium (*https://makeitwood.org/benefits/insulator.cfm*). Wood's low thermal conductivity means that 90% of its insulation value can be realised, with only 10% lost to thermal bridging. Wood loses less heat through conduction than other building materials, and wood-frame construction techniques support a wide range of insulation options, including stud cavity insulation and exterior rigid insulation. Timber structures from frame walls to CLT panels provide cavities for additional insulation materials if necessary, for meeting energy efficiency regulations. This means that thinner walls and less insulation materials are required in wood-frame buildings compared to steel and concrete structures to achieve the same level of thermal resistance.

Embodied energy - which is the energy required to harvest, manufacture, transport, install, maintain, and dispose or recycle a material - also contributes to wood's light carbon footprint. LCA studies consistently show that wood performs better than other materials in terms of embodied energy. One reason why wood performs well is that wood and wood products require far less energy to manufacture than other materials and very little fossil fuel energy, since most of the energy used comes from converting residual bark and wood residues to electrical and thermal energy.

New wooden building systems have been developed that offer greater air tightness, less conductivity and more thermal mass. They include prefabricated systems that contribute to the low energy requirements.

2.4 Versatile, Efficient Wood Building Products and Technology

Wood has several characteristics that makes it a highly versatile building material:

- light and easy to work with, can be moulded into biomorphic forms;
- bears compression and traction forces;
- has good thermal insulation properties;
- one can flexibly combine different wood components, creating structures that together deliver the best possible load-bearing capacity, thermal, acoustic and moisture insulation, and fire resistance;
- can be applied as a structural, insulating and surface material as well as an interior material; and
- wood constructions are easy to dismantle, and wood can be reused, recycled into panels, and finally recovered as energy, leaving almost no waste for disposal, consistent with the principles of a circular economy.

As an interior material wood has been used in all kinds of buildings as a wall, ceiling, floor, and furniture material. As a structural material it has been traditionally used in single-family buildings, for example, in the

Nordic countries, the UK, Germany and the USA. Within the EU, with 8–10% of single-family buildings have a wooden frame. The use of wooden frames ranges from above 80% in Nordic countries to near zero in many southern European countries. Due to the emergence of engineered wood products and new building systems in recent decades, wood is increasingly used also in large-scale construction (office buildings, day-care centers schools and multi-storey residential buildings, as well as in commercial, industrial and agricultural buildings).

In the past 10 to 15 years, the development of new heavy timber products - CLT, glued laminated wood (glulam) and LVL - has opened the door to taller and bigger buildings with wood as the primary building material. The development of these products and advancement of manufacturing of prefabricated wood components and pre-finished building products has facilitated the move towards off-site production of components and modules, reduced transport costs, reduced on-site construction time, reduced damage due to changing weather conditions, and reduced on-site waste handling.

The construction industry is undergoing a transition moving work from building sites to off-site manufacturing plants, where elements and modules are precisely dimensioned and assembled in industrial factory conditions and delivered to building sites for quick installation. The use of prefabricated wood modules allows assembling a building in just ten weeks after the foundation slab has been cast compared to traditional concrete buildings requiring several months to build up. Brock Commons Tallwood House is an innovative 18-storey tall wood hybrid building at the University of British Columbia that was complete in about 70 days after the prefabricated components arrived on site, approximately four months faster than a typical project of this size.

Wooden bridges are another example of the superior technical and economic potential of building in wood. A wooden bridge can be prefabricated, transported, and installed on site in sections that are practically complete.

These developments, combined with digital design and fabrication techniques, are opening new possibilities for architectural design, creating of aesthetically novel buildings that are healthy to live in. Wood and digital processes have introduced a great degree of flexibility into the design and construction process, including constructing buildings with biomorphic shapes.

Glue-laminated Timber (Glulam)

Glulam comprises several wood laminates bonded together with adhesive. It is designed for load-bearing structures and other structural material in multi-storey buildings. Glulam offers great strength and stiffness in relation to its weight, and glulam beams can freely span large distances up to 30 m. Glulam wooden structures can be installed or erected in all directions, and in the desired length and shape. Considering how exceptionally strong it is, glulam is a lightweight construction material. Its use has relatively few limits, as the beams can be straight, convex or curved. Glulam has a reputation for being used in exposed applications, such as bridges, vaulted ceilings and in designs with large open spaces, such as sport halls, libraries, warehouses, airport and other terminals. Good examples in Finland include the Sibelius Hall and Piano Paviljonki in Lahti.

It is also possible to combine the use of glulam and CLT as was done in Mjøsotårnet in Norway, the world's tallest wood building, and the tallest wood structure in Australia - 25 King in Brisbane – completed in 2018.

Photo: Wooden structures in the Sibelius Hall in Finland, Dasos Capital (Nora Anttonen); Mjøsotårnet in Norway, Jens Edgar Haugen Voll Arkitekter AS

Cross-laminated Timber

CLT panels consist of layered lumber boards (usually three, five or seven) stacked crosswise at 90-degree angles and glued into place. Finger joints and structural adhesive connect the boards. CLT resists high-racking and compressive forces, so it can be especially cost-effective for multi-storey and long-span applications. CLT is a highly flexible wood product that is easily tailored for further processing and can be used together with any building material. CLT is five times lighter than concrete and 15 times lighter than steel – and as strong. Because of its dimensional stability and structural properties, this massive wooden product is well suited for floors, walls. and roofs. CLT panels are pre-cut to size using computer-controlled cutting machines which make complex cuts with high precision.

CLT panels are generally prefabricated before transported to the building site. Modules can be prefabricated in factory conditions to a ready-to-move states, which speeds the transport and construction process. A high degree of prefabrication and high precision can be achieved. The construction process using CLT is characterised by faster completion times, less demand for workers on site, and less disruption to the surrounding community. Time saving can be from 20 to 70%.

CLT is gaining an increasing market share in the construction of multi-storey buildings. The use of prefabricated wooden facade elements in the renovation of old concrete apartment blocks has also proved to be a cost-effective and technically feasible method for renovation with improved energy efficiency, which is likely to increase the demand for CLT and sawnwood in construction throughout Europe over time.

In 2020, the worldwide CLT production is estimated at over 2 million m^3 because of numerous large-scale projects. Production is projected to increase by 10% a year in the next five years. More than 95% of the capacity will be in Europe and North America. Central Europe contributes to 60-70% of this amount.

Stora Enso has three CLT mills with a total capacity of 270 000 m^3: Gruvön in Sweden and Ybbs and Bad St. Leonhard in Austria. It will add a new CLT production line at one of its sawmills in the Czech Republic with an annual production capacity of approximately 120 000 m^3. Stora Enso has developed a new flexible, modular wooden office concept, which meets all requirements for open space, grid space and clear ceilings, and meets fire safety and acoustics regulations.

The Finnish Nature Center Haltia in Espoo was constructed using CLT. Other Finnish examples include Joensuun Elli and Puukuokka. At its time of completion in 2015, Puukuokka in Jyväskylä was the tallest wooden apartment block in Finland and one of the first high-rise examples of prefabricated CLT construction in the world at that time. The 100-meter-high Timber Tower in Hanover is made of CLT. The Library at the Dock in Melbourne, opened in 2014, is the first public building in Australia that was made with CLT (supplied by Stora Enso). The International House Sydney also used Stora Enso CLT. In 2020, the huge low-carbon, low-energy Microsoft Silicon Valley campus was completed; it is the largest mass wood (CLT) structure built to date in North America. The 18-storey Brockhouse Commons wood hybrid building in Canada is comprised of 17 stories of mass timber construction above a concrete podium and two concrete stair cores. The floor structure consists of CLT panels supported on glulam columns.

Source and photo: Library at the Dock in Melbourne, stora.enso.fi and Puukuokka in Jyväskylä, Finland, Mikko Auerniitty, puuinfo.fi

Laminated Veneer Lumber

Laminated veneer lumber (LVL) is another advanced engineered wood construction material, suitable for similar end-uses as CLT. It is one of the strongest wood-based construction materials relative to its weight, and can hence provide a solution when strength, dimensional stability and high load-bearing capacity are essential. Applications include joists, trusses, posts, beams, prefabricated components of roof, floor and wall elements, and door and window manufacturing. In addition to construction, LVL can be used in trailer and shipbuilding industry, wind power installations, and other complex engineered structures.

Metsä Wood is Europe's biggest LVL producer with five production lines (Kerto® wood). The company's LVL mill capacity in Lohja, Finland, was expanded in 2017 by 20 000 m^3 and a new 65 000 m^3 LVL production line was launched in 2019 in Punkaharju, Finland. Stora Enso has 100 000 m^3 LVL capacity built in an existing paper and paperboard mill in Varkaus, Finland.

Wood City in Helsinki is a well-known example of using LVL in large-scale construction combining modern architecture with principles of green building construction. Examples of buildings constructed of Kerto® wood are Metropol Parasol in Seville, DB Schenker terminal building, and FMO Finnforest Modular Office Tapiola.

Box 2 Cross-laminated Timber: A Versatile, Environmentally Friendly Wood Product

- CLT is an innovative product based on (spruce) sawnwood.
- Produced in the form of large-format planar elements.
- Consists of individual cross-glued lamellas, i.e., layers of wood 3, 5, 7 or more.
- Massive, flexible wood construction material; basically, no limits are set to the form of CLT.
- Very cost-efficient in multi-storey construction; can be erected in half the time needed for a concrete building.

Source: Stora Enso

- CLT and timber structures, in general, can be built by using less natural resources and energy than other structures.
- CLT houses/construction act as carbon sinks: 1 m^3 timber stores 0.9 t CO_2.
- Formaldehyde-free and environmentally friendly glues are used in gluing process.
- New technological development and standardisation allow modular construction system; accurate and ready for erection.

Source: Stora Enso

2.5 Health and Well-being Impacts

Using wood as a construction material has important potential health and wellbeing effects. Solid, peer-reviewed comparative analysis of the impacts of construction materials on air quality and their link to health is still limited but accumulating. Several studies have already reported possible health benefits of wood, looking at both measured and perceived indoor environment quality (IEQ).

In 2020, a mega-analysis of 140 publications (Alapieti *et al*. 2020) found that wooden interior materials exert mainly positive or neutral effects on IEQ, such as moderating humidity fluctuations of indoor air, inducing positive feelings in occupants, and inhibiting certain bacteria. Negative effects on IEQ are limited to volatile organic compounds emitted from wood products depending on the species and chemical treatment used which are regulated.

The use of wood products as hygroscopic material can improve indoor air quality by moderating humidity. Acting like a sponge, wood absorbs or releases moisture to maintain equilibrium with the adjacent air. This raises humidity when the air is dry and lowers it when the air is moist therefore improving air quality. Researchers at Aalto University in Finland and the Norwegian Institute of Wood Technology have shown how wood absorbs and emits moisture, contributing to a better indoor environment. The ability of wood to moderate humidity is particularly important in workplaces. In a focus group study by Strobel *et al.* (2017), interior wood use was seen to improve indoor air quality.

Biophilic Architecture and The Impacts Using Wood

The strongest evidence of wood's health and well-being benefits is based on wood's biophilic properties. Biophilia refers to humans' innate need to connect with nature. There is scientific evidence that when individuals have contact with nature, their neurological, physiological, and psychological responses result in less stress, lower blood pressure, more relaxation and positive moods, and increased concentration. In this context, wood is particularly interesting, as it is a natural, renewable, and already widely used in the construction industry. Biophilic architecture is an emerging approach to design that provides humans with health-promoting psychological and physical connections to nature in their built environments. Biophilic architecture includes the use of wood as a visible structural and interior design material.

Examples of the health benefits of biophilic building design include:

- There is cumulative evidence from studies examining the psychophysiological effects of wood indoor environments on occupants which shows that wood can contribute to stress reduction or recovery from stress. A study conducted in British Columbia provides evidence that wood surfaces in an office lower the body's sympathetic nervous system (decreasing blood pressure and heart rate), thereby reducing stress. A recent study at the University of British Columbia and FPInnovations identified a link between the use of wood and human health (Augustin and Fell 2015). The study compared the stress levels of participants in different office environments with and without wood finishings and concluded that stress was lower in the wood room compared to rooms without wood.

- Students taught in wooden classrooms have decreased heart rates and decreased perception of stress from interaction with teachers according to an Austrian study (Kelz *et al.* 2011).

- European research compared occupants' responses to wood and plaster indoor settings and found out that wood elicits more positive emotions.

- In Australian workplaces, exposure to wood has been shown to lead to higher levels of concentration, worker satisfaction and increased productivity, as well as reduced sick leave and overall higher wellbeing. A strategic market research firm Pollinate and the University of Canberra surveyed 1 000 indoor workers. According to the study (Knox and Parry-Husbands 2018), employees in offices featuring natural wooden surfaces reported higher personal productivity, mood, concentration, clarity, confidence, and optimism on average.

- In Japan, a scientific study indicated that regular use of wood products significantly increased the social interaction and activity levels of the elder in assisted living spaces. Thus, use of wood products may enhance the possibility of preventing mental and physical decline of frail elderly.

- Resident surveys conducted in wooden apartment buildings indicate that a wood building does not cause allergies in residents in the same way as many other materials do.

3. INTERNATIONAL WOOD CONSTRUCTION TRENDS

KEY MESSAGES

- *The share of wood construction of total housing starts has been increasing in the Nordic countries.*
- *The use of wood frames and wood in general in construction is increasing in several Central European countries, North America, Japan, China and Australia.*
- *Many of these countries already have considerable experiences in large-scale modern wood construction, including tall wood building based on modern architecture and design approaches.*

3.1 Status of Wood Construction and Related Policies and Programs

There are significant differences in the popularity of wood construction in Europe. Concrete traditionally dominates in all building categories in the southern Europe. From the perspective of reducing emissions from the building sector, Southern Europe offers potential but tradition and personal preferences create constraints for residential wood construction.

The traditions of residential wood construction are strong especially in the Nordic countries and the Alps because of the proximity to the forest resources and cultural reasons. The share of wood-frame 1-2 story residential houses is already very high in the Nordic countries, reaching about 90 percent in Finland and Sweden. The construction tradition in Denmark has been based more on the Central European traditions using brick and stone. Wood-frame residential houses are not that common in the rest of Europe, except for Southern Germany, Austria, Northern Italy, and certain parts of Switzerland and Ireland. However, in countries such as the UK, Germany, Austria, Switzerland and France, wooden multi-storey houses and wood-based offices, schools, and day-care centers are becoming increasingly common, often combined with contemporary architectural design.

In Germany, the use of wood in construction has been increasing in all building types. In single family houses, the share of wood-frame houses has increased from about 13% in 2005 to 20% in 2019. In 2019, the share of wooden multi-storey houses was about 2% compared to 1% in 2010.

Outside Europe, wood-built housing occurs primarily in the USA, Canada, Japan, Australia, and parts of South-East Asia and more recently in China. Wood has a long tradition as a construction material in residential buildings in Canada and the US. Especially in the West Coast, over 90% of the three to five-storey residential houses are made of wood. In Canada, tall wooden towers up to 18 storeys have been built.

The “green trends”, people’s preferences concerning architecture, technological development, and regional, national, and sub-national policies as well as zonation directly or indirectly, increasingly favour the use of wood in construction. The political support for the use of wood in construction has become quite strong in many countries; policies and programs have been introduced to increase the use of wood in large-scale construction.

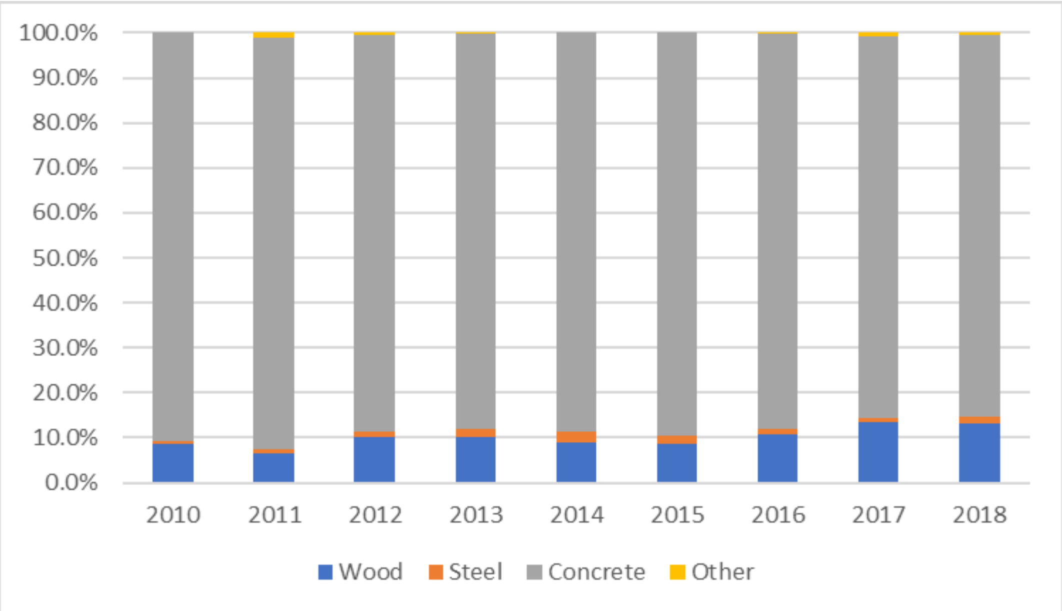
- Countries like *Finland* and *Sweden* have national wood building programs with explicit targets e.g., for the share of wood-framed multi-storey buildings of new construction and use of wood in public buildings as well as large constructions, such as bridges and halls. The Swedish Government has presented a wood building strategy. In Sweden, the construction sector's roadmap for 2025 was introduced in 2019 emphasizing the need increase (industrial) wood construction to increase the climate benefits and promote exports and employment in the whole country. Sweden had a national strategy for “more wood in construction” already some 20 years ago,

- *Norway* is rapidly shifting towards a greener construction industry, with environment-friendly materials, zero-emission construction sites and smart, energy-efficient buildings and replacing steel and concrete with massive timber as a construction material. Norway is soon adopting regulations for low-carbon construction.

- The *French* government has plans for a sustainability law that will mean that all new public buildings will be built from 50% timber or other bio-based materials, as part of President Macron's drive for the country to be carbon-neutral by 2050. France has the high-rise wood-based building initiative ADIVBOIS. Further, the government requires that new public buildings have at least 0.2 cubic meters of wood for every 1 square meter of floor area.
- In *Scotland*, the Climate Change Plan (2018) states: "Increase the use of sustainably sourced wood fiber to reduce emissions by encouraging the construction industry to increase its use of wood products where appropriate."
- In *New Zealand,* wood or wood-based products must be considered as the main structural material for new government-funded buildings up to four floors.
- The *Japanese* government introduced the Act for Promotion of Use of Wood in Public Buildings, requiring wood to be considered as the primary building material for any government-funded project up to three stories, and for any privately funded building used in a public manner, such as elderly care facilities.
- In *Canada*, the governments of British Columbia (Wood First Act), Ontario, and Quebec (Québec Wood Charter) have policies that encourage the use of wood in public buildings. Further, Canada has introduced the national Green Construction through Wood Program that provides incentives for wood building construction. The 2020 National Building Code of Canada allows high-rise mass timber construction. British Columbia has doubled height limits allowed for timber towers.
- The ICC in the *United States* approved changes, effective in 2021, that will permit mass timber construction of up to 80 meters (18 storeys). This change was made possible by strong evidence of the fire safety properties of mass timber construction, coupled with governments' commitment to reduce CO2 emissions. Wood use is also promoted in public buildings in Maine and Oregon.

An example of what kind of impacts national initiatives can have comes from Sweden where the national wood construction strategy for multi-storey and public buildings and constructions was developed in 2004. In less than 10 years the share of wooden multi-storey buildings increased from about 5% to about almost 15% and in long term the share of 30% is seen as feasible (Figure 5).

Figure 5 Share of Wooden Multistorey Houses of Total Multistorey Housing Starts in Sweden in 2010-2018



Source: Statistics Sweden, Forecon Oy

3.2 Wood Construction Is Increasing in Many European Countries

In Finland, Norway, and Sweden the biggest potential in increasing the use of wood in construction lies in multi-storey residential buildings, offices, and public buildings because wood already dominates the construction of single houses and vacation homes. Building codes in many European countries increasingly incorporate engineered wood products, and their structural design values enable them to compete successfully with concrete and steel in the construction of tall and large buildings. The past two decades have seen a rapid development of wood in architecture because of the EU's switch to function-focused standards in the member states' building regulations, allowing also building tall buildings using wood-based systems.

There are also regional initiatives to promote the use of wood in construction. Build-in-Wood is a European-funded Horizon 2020 project with the goal of drastically increasing the proportion of timber construction. With EUR 10 million support from the EU, a consortium of 21 European companies and organisations has been formed to make timber the material of choice for multi-storey buildings gradually replacing steel and concrete. The aim is to remove barriers to timber construction by developing standard, industrialized timber building systems, while assessing and documenting the environmental, economic, and social benefits. The group believes that timber could be used to build an estimated 1.6 million new apartment units needed every year across Europe.

In 2019, the Nordic Prime Ministers of Denmark, Finland, Iceland, Norway, and Sweden set themselves a goal for the Nordic region to become 'a global leader in combating climate change and achieving a more sustainable society'. This goal has also been set for the built environment by the Nordic declaration on low-carbon construction of Nordic ministers responsible for construction and housing in October 2019 (Nordic Council of Ministers 2019). According to the declaration, the five counties agree to collaborate towards the harmonization of a life-cycle approach to buildings.

The Finnish Technical Research Institute VTT, as part of the EU LeanWood project, has studied wood construction trends and opportunities in Europe. The report identified political support and a growing common interest in sustainable buildings and good reputation of timber as an ecological material with a low carbon footprint compared to other common building materials as the main strengths of building with timber in Europe. The study identified major opportunities for wood in low-carbon construction and buildings.

The study also identified weaknesses and threats that related especially to restrictive building regulations and inadequate capacity and interest of large construction companies (Table 1).

Table 1 Building with Timber in Europe – a SWOT Analysis

Strengths	Weaknesses
Political support Common interest in timber buildings Good supply of raw material Well-established value chain New markets through research and development Broad existing base of the timber manufacturing industry Fast and lightweight construction	Building regulations (fire and acoustics) Shortage of qualified experts Resistance to change by large construction companies Usually perceived as more expensive than established construction methods and materials
Opportunities	**Threats**
Bioeconomy becoming a strong topic in Europe Evolving climate policies and a drive for low-carbon construction and buildings Versatile properties of wood Good for urban densification Agile mass customization Streamlining the design and construction processes	Low level of ambition in wood construction among large construction companies Building with wood yields no compensation for reduced life-cycle costs Lack of skills of the design professionals Regulations favouring other building materials Performance of the whole competence chain

Source: Nykänen et al. 2017.

In recent years there have been positive developments concerning the various weaknesses and threats. The skills of architects and designers have improved, and most importantly, they are becoming more engaged with wood building. Tall timber buildings have caught the attention of architects, quantity surveyors and the media in Europe, and wood construction has strengthened its profile in the eyes of the public and architectural community. Contemporary high-rise wood buildings – representing often “vow architecture” - have recently received a lot visibility in Europe.

Currently, the tallest wood building in Europe is Mjøstårnet, an 18-storey mixed-use building in Brumunddal, Norway, completed in March 2019. It is officially the world's tallest timber building, with a height of 85.4 m. It was made using glulam beams and CLT panels. The second tallest is 84-meter, 24-storey high ‘HoHo Tower’ - timber-concrete hybrid commercial-residential development - in Vienna, Austria. Around 76 percent of the structure is constructed from wood.

In Strasbourg Deux-Rives, the Sensations was the first apartment building in France made almost entirely of wood (CLT); it was completed in 2019 by the Woodeum company. The 11-floor tower was erected exceptionally quickly, in eight weeks, which is half the time of a concrete building. These three wood-framed apartment blocks are the highest wood buildings in France with one at 11 floors and two others at eight. In total, they will provide 146 homes. The same company is behind the Porte Brancion project in Paris which includes three blocks containing student and young professional apartments, shops, and a sports complex, and is being built over the Paris ring motorway, Périphérique. Woodeum is a French company leading in low-carbon real estate development for new constructions and renovations, especially massive timber structures. It has undertaken many building projects in France using Stora Enso's CLT products.

Fire safety of wood buildings, especially in high-rise buildings, has been a big concern in many countries. However, in the last ten years there has been a lot of research and fire testing internationally to better understand the fire performance of timber building elements. Results indicate that in most building fires it is the contents rather than the construction materials which provide the main fire load, and that light timber frame buildings meet the functional safety requirements that are required for non-combustible steel or concrete buildings. Contrary to popular belief, mass timber buildings are fire resistant. When exposed to fire, the outer layer chars and acts as a protective coating, insulating the wood underneath. Fire tests have proven that due to the charring process in wood beams they remain structurally sound longer than steel. The improved knowledge has allowed changes to codes to increase the height limit for wood buildings like has been done in the US, Canada and most Nordic countries. FPInnovations in Canada tested CLT panels as walls and floors and concluded that the panel fire performance is comparable to non-combustible building elements like concrete. As a result, the use of CLT has been adopted into the prescriptive building codes in the US and Canada (Barber 2018).

However, fires pose special risks for all types of high-rise buildings as exemplified by the Grenwell Tower fire killing 71 people in London in 2017. The growth trajectory of CLT for high-rise residential buildings in the UK changed in December 2018 when the new legislation, post-Grenfell, determined that no combustible material should be present in the outer cavity of “accommodation” buildings over 18 m tall. The higher-rise CLT buildings built before that date, such as those mentioned above, all had an external superstructure of CLT. The new legislation did not explicitly ban the use of CLT but creates challenges for its application. Height restrictions multi-storey wood buildings have also been discussed.

In general, building codes and regulations in Europe have become more flexible from the perspective of wood construction; there has been an international shift to performance-based building codes. When it comes to fire codes, they treat in principle all materials equally; the focus is on fire performance.

Considering the weaknesses, the market prospects for increasing wood construction - including multi-storey residential, office and public buildings – are so good that it will be essential to increase in future the production capacity of engineered wood products, such as CLT and LVL.

4. WOOD CONSTRUCTION IN FINLAND

KEY MESSAGES

- *The use of wood and wood-based products and elements in construction of multi-storey building, public building and office and commercial buildings is projected to increase significantly in the coming 20 years.*
- *There is an immense potential in the construction sector for wood industry as new technologies enable replacing concrete and steel with wood elements also in large scale construction.*
- *The government policies, programs and regulations explicitly promote wood construction as a sustainable, low carbon approach contributing to the national emission reduction targets.*

4.1 Current Status of Wood Construction in Finland

Wood buildings have a long tradition in Finland, possibly because of the availability and proximity to significant forest resources. In the 18th century, entire cities were built using solid wood. In recent years, 85-90% of single-family houses have been made of wood, and a very high share also applies to new construction. In 2019, the share of wood in all new construction was about 28%. The overall share of wood-frame construction has been declining somewhat in the last 15 years due to rapid urbanisation and increasing share of multi-storey residential construction, although the use of wood in non-residential construction has been increasing.

In the past the use of concrete dominated multi-storey buildings. Only in the recent years, the share of wood-frame high-rise buildings has increased but it is still very small at 3-4%. As of fall 2020, there were some 100 multi-storey residential buildings. The construction of wooden multi-storey buildings intensified in 2010 with the introduction of CLT elements, imported from Austria by Stora Enso. In 2014, Oy CrossLam was established by Kuhmo Ltd: and later new operators, such as Hoisko Oy, started to manufacture CLT elements for construction. Figure 6 demonstrates the rapid increase since 2015 in the construction of apartments in wooden residential multistorey buildings. At the same time, the use of wood in public buildings, such as day-care centers and schools, has increased rapidly. In 2010-2019, 475 wood-frame day-care centers and 273 schools were built. Problems with indoor air quality has increased the popularity of wood in public buildings, such as schools. The share of wooden public buildings has reached 16%. The share of wood-frame commercial and office buildings has also increased rapidly reaching 16% (based on Forecon Oy statistics).

Figure 6 Number of Apartments in Wooden Residential Multistorey Buildings and in All Residential Multistorey Buildings in Finland in 2010-2018

Source: Ministry of Economic Affairs and Employment 2020.

The increased popularity has also been driven by the change in building regulations in 2011, allowing construction up to eight stories compared to the earlier three-storey limit. Fire codes were changed in 2011 to also allow the use of wooden frames and façades in residential and office buildings of 5–8 storeys. In addition, the possibilities for using wood were extended to cover repairs of and extensions to suburban concrete buildings. After the fire code modifications in 2018, the construction of even higher than 8-storey residential buildings has been allowed.

The highest multi-storey building in Finland was completed in 2019; Joensuu Lighthouse has 14 floors and is 50 meters high.

Wooden office and public buildings have also attracted the interest of constructors and architects. Even though modern wood construction is still to make a proper breakthrough in Helsinki, there are a growing number of examples. The internationally recognised Oodi Library (2018), an example of "wow architecture" in Helsinki, has plenty of wood in the external and interior walls, roof, and stairs although the frame is made of steel. The library is a nearly zero-energy building, designed for ease of maintenance with easily replaceable wooden elements.

Photo: Tuomas Uusheimo. Oodi Library in Helsinki (https://nomuwood.com/cases/oodi/); puuinfo.fi

The new headquarters of the international mobile game company Supercell is part of the unique Wood City block in the Jätkäsaari district of Helsinki. It was completed in January 2021. For this project, SRV, Stora Enso and Sweco developed new solid wood structures. The 8-storey office building was built using pillar beam elements of LVL stiffened with concrete shafts and adaptable bolting. Stora Enso, together with the Finnish pension insurance company Varma, is constructing a new head office that is planned to showcase environmentally friendly, low-carbon wood construction technology and modern architecture in Katajanokka, Helsinki.

4.2 Potential for Increasing Wooden Multi-storey Residential and Non-Residential Buildings in Finland

The government has now set targets for the use of wood in all types of public construction and is implementing practical measures to reach the targets. Further, by 2025, at the latest, the law will mandate how large the carbon footprint of a building's life-cycle can be. Maximum emissions are to be defined for materials, construction sites, use, and even future dismantling of buildings.

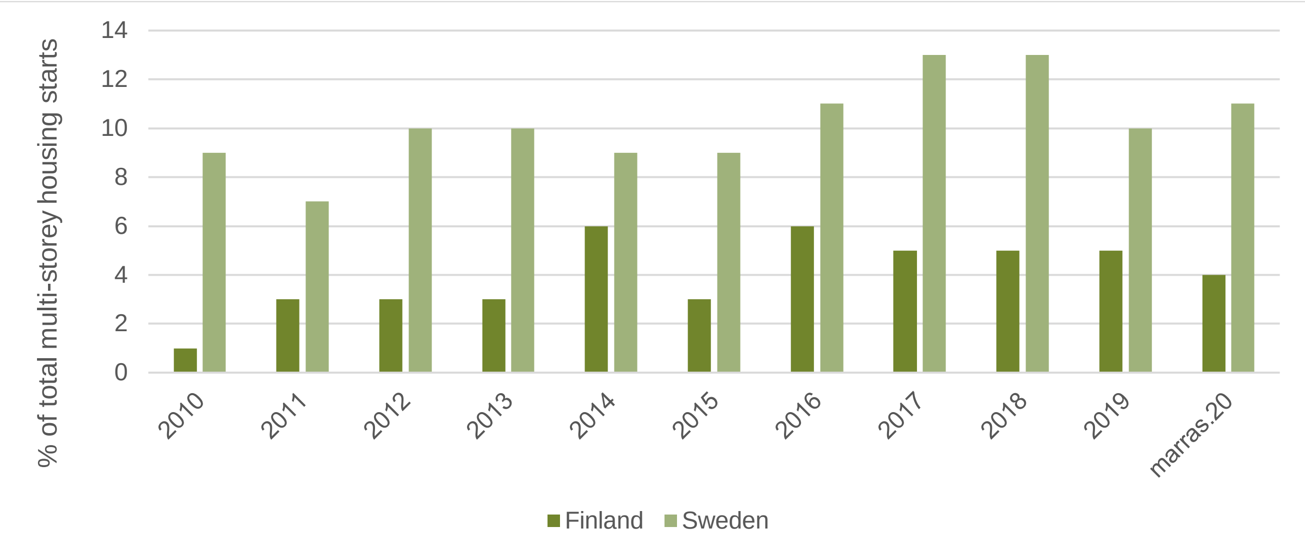
Architects and designers have become more interested in the use of wood and green construction in general. Attitudes in the construction sectors are also changing and wood is becoming more acceptable as a raw material. Further, a new wood construction degree program has been launched in Tampere University. Big construction companies, like YIT, Skanska, and NCC, are increasingly interested in wood construction.

Wood construction and related element/module production are soon taking place at a scale, which will level construction costs with the cost of concrete construction attracting new investments. Recent research in Sweden indicates that when the construction of wooden multi-storey buildings started some 25 years ago, wood construction costs were clearly higher than the costs of "traditional" concrete construction; now they can be up to 20% lower. Similar development can take place in Finland.

The Swedish wooden multi-storey building construction trends to illustrate the immediate potential of wood in construction in Finland. The country should in principle be able to triple wooden multi-storey construction in the next five years. However, the national Wood Building Programme had set a market share target of 10% for wood-fare multi-storey buildings by 2020, yet in 2019 only 4% share was reached. On the other hand, in 2020 the construction plans amounted to 12 000 apartments, which, if realised in the next five years, would increase the share to 10% or comparable to the current Swedish level (Figure 7).

A recent study by consulting company Granlund Oy (2020) has presented new projections of wood-based construction, covering all construction types. The base scenario is based on a 35% market share for new wood-frame multi-storey buildings by 2035. The corresponding shares for public building would reach 65% and office and commercial buildings 50%. These scenarios are based on existing know-how, products, technology, and building regulations and codes as well as industrial capacity (Table 3).

Figure 7 Comparison of Market Share of Wood-Frame Multistorey Housing Starts in Sweden and Finland in 2010-2020



Source: Statistics Finland, Statistics Sweden, Forecon Oy.

Table 2 Scenarios for Wood-frame Building Construction Shares up to 2035

	2017		Base Scenario 2035 (existing solutions used)		Optimistic Scenario (new innovations adopted	
Type of building	Wood	Other material	Wood	Other material	Wood	Other material
	%					
Residential (1-2 story)	80	20	90	10	90	10
Residential multi-storey	5	95	35	65	50	50
Other residential including vacation homes	98	2	98	2	98	2
Office and commercial	12	88	32	68	50	50
Public	27	73	65	35	65	35
Industrial	22	78	35	65	50	50
Other residential including vacation homes	69	31	75	25	75	25

Source: Viitala, A, 2020.

National Policies, Programs and Regulations Accelerate Wood Construction in Finland

The national Wood Building Programme (2016–2022) is a government undertaking coordinated by the Ministry of the Environment aimed at increasing the use of wood in construction and thereby increasing the long-term carbon storage. Other objectives are to promote and develop the skills and know-how for lifting wood construction onto an internationally competitive level and to support industrial wood material manufacturing in Finland, and to boost exports aligned with the Finnish Bioeconomy Strategy. There are five focus areas:

- Increasing the use of wood in urban development;
- Promoting the use of wood in public buildings;
- Increasing the building of large wood constructions;
- Strengthening of regional skills bases; and
- Promoting exports.

The current Government Program introduced in 2019 addresses explicitly wood construction and identifies ways to accelerate the implementation of the Roadmap for Low Carbon Construction sector. The government identified actions relate to target setting for public wood construction, strengthening related education, training and research and development, as well as introducing a subsidy scheme for wood construction in publicly supported residential construction schemes. The objective is to develop a low-carbon society and support sustainable urbanisation. Increasing the amount of wood used in construction is one way to help to attain the energy and climate targets laid down in the National Energy and Climate Strategy and to reduce Finland's carbon footprint by 2030.

Renovation, including adding floors to existing concrete buildings, also offers opportunities for increasing the use of wood. Wood weights only about 20% of concrete and suits thus well for topping floors. This potential remains to be fully tapped due to prevailing municipal regulations.

In 2019, the share of public new construction of total new construction was 18%. Out of that the share of wood construction was 15%. The current government has set a target for increasing public wood construction significantly so that in 2025 it would amount to almost half of the public construction (Table 3). Municipalities will be supported to meet the targets.

Targets were also set for the various types of construction. The biggest increase is planned for publicly funded multi-storey residential houses (Table 4).

Table 3 National Target for Increasing the Use of Wood in Public Building Construction in Finland 2019-2025

	Total construction	Wood-frame buildings	Share of wood construction
2019	6 907	1 039	15%
2022	5 661	1 760	31%
2025	5 221	2 296	45%

Source: Ministry of the Environment (Finland)

Table 4 National Targets by Building Category for Increasing the Use of Wood in Public Construction in Finland up to 2025

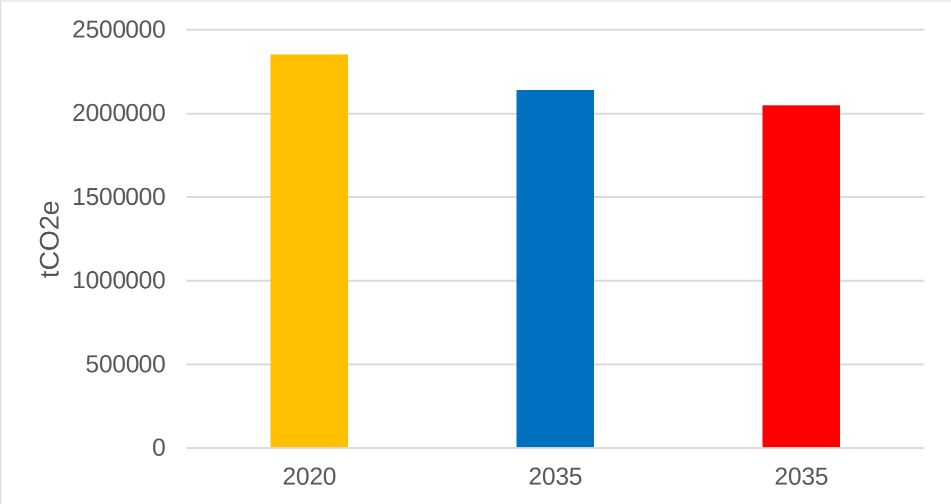
	Wood-frame multi-storey residential	Wood-frame educational buildings	Wood-frame health facilities	Meeting/office facilities
2022	21%	55%	20%	20%
2025	46%	65%	35%	30%

Source: Ministry of the Environment (Finland)

The scenarios developed by Granlund Oy (Figure 8) were used to assess and compare the carbon footprints of wood construction versus using concrete. This analysis applies LCA and included substitution effects which had not been used in similar type of analysis before.

The analysis demonstrated that, according to the base scenario, it is possible to significantly reduce, by 7-11%, the annual CO2e emissions of the construction sector using wood-based solutions in all types of new buildings. This would not require development and/or adoption of new technological solutions and innovations. In case of multi-storey construction and office/commercial buildings, the reductions were estimated to be 13-20% and 10-17%, respectively (Figure 8 and Figure 9).

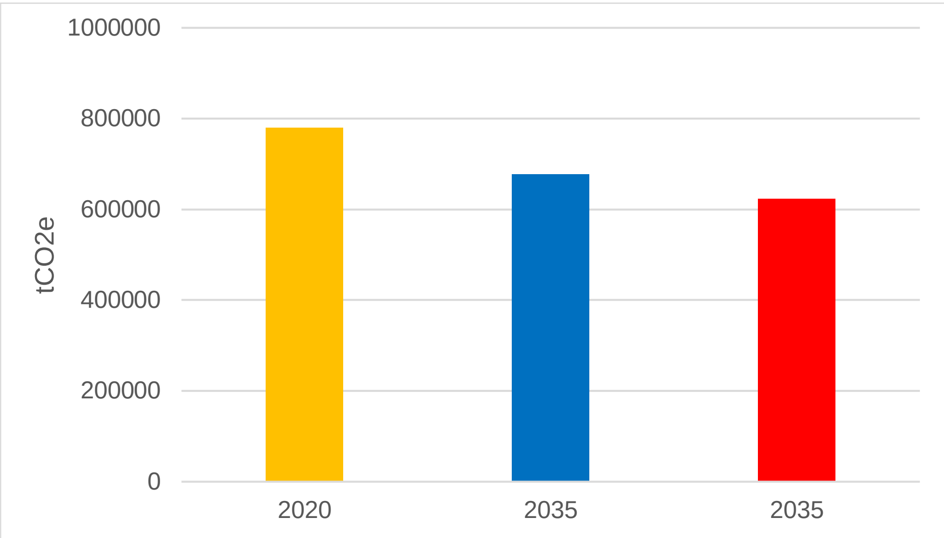
Figure 8 Potential to Reduce CO2 Emissions in the Construction of New Buildings in Finland 2020-2035



Source: Viitala, A, 2020

Blue bar Base scenario
Red bar Optimistic scenario

Figure 9 Potential to Reduce CO2 Emissions in the Construction of Multi-storey Buildings in Finland up 2020-2035



Source: Viitala, A, 2020

Blue bar Base scenario
Red bar Optimistic scenario

It is important to note that, in addition to reduced emissions, increasing the share of wood construction (the base scenario) would also increase the accumulated carbon stock in the built environment. By 2035, the increase in the stock would be 40% higher compared to the increase based on the current shares of raw materials in new construction.

4.3 Recent Examples of Wood Construction in Finland

In this section, relatively recent examples of wood construction covering residential multi-storey, multi-storey office and public buildings in Finland are presented (see Box 3, Box 4 and Box 5).

Box 3 Puukuokka Wooden Residential Building and Tuupala Wooden School

Puukuokka Residential Building, Jyväskylä, Finland

- An eight-storey residential block house made using Stora Enso CLT, designed by Lassila Hirvilammi Arkkitehdit Oy.
- Winner of architecture Finlandia-award in 2015.
- The buildings are assembled from pre-fabricated elements minimizing the construction time at site.
- Wood is kept visible in floors, ceilings, and windows as well as in the façade, which is in painted spruce and untreated larch.

Photo: Mikko Auerniitty; puuinfo.fi

Tuupala Elementary and Preschool, Kuhmo, Finland

- First school made of CLT in Finland, designed by alt Architects, completed in late 2017.
- The size of the building is 5 500 square meters.
- Gained a lot of attention both in the building and completion phase and received an award in 2017.

Photo: Mikko Auerniitty; puuinfo.fi; alt Arkkitehdit Oy and Arkkitehtitoimisto Karsikas Oy

Box 4 Supercell Hybrid, Wooden Head Office and Wooden Stora Enso Head Office in Helsinki

Supercell Head Office in Helsinki

- 8-storey office building completed in January 2021.
- SRV, Stora Enso and Sweco developed new solid wood structures; pillar beam elements of LVL.
- Stores carbon equalling the annual emissions of 600 cars.
- Applied for Leadership in Energy and Environmental Design (LEED) Platinum certification.

Photo: Stora Enso

New Stora Enso Head Office, Helsinki, Finland

- International architecture competition to showcase environmentally friendly low-carbon wood construction technology and modern architecture.
- Makes use of the Office Building Concept by Stora Enso
- Aims at gaining LEED Platinum certification.

Photo: Stora Enso, Anttinen Oiva Arkkitehdit Oy

Box 5 Examples of Use of Wood in Sustainable, Modern Construction in Finland 1994-2014

Kamppi Chapel, Helsinki 2012. K2S Architects

Daycare Center Tillinmäki, Espoo 2012.
A-Konsultit Architects

Sibelius Hall, Lahti 2010. Photo: Mikko Aureniitty; puuinfo.fi;
Artto Palo Rossi Tikka Architects.

METLA (Finnish Forest Research Building, Joensuu.
Photo: Jussi Tiainen;puuinfo.fi; Arkkitehtitoimisto SARC Oy.

Photos: Dasos Capital (Nora Anttonen), if not otherwise mentioned

5. INVESTING IN WOOD CONSTRUCTION

KEY MESSAGES

- *Green buildings, wood buildings included, are becoming increasingly attractive investment targets for institutional investors, private equity funds and commercial banks internationally and in Finland.*
- *The total EU market is estimated at around EUR 5 billion for multi-storey residential, office and public building construction with an average annual growth rate of 8% (EUR 450-650 million p.a.) in 2021-2030. In five years, the market is estimated at EUR 7.5 billion and by 2030 the market is estimated to exceed EUR 10 billion.*
- *The average annual market for constructing new wooden multi-storey residential buildings in Finland can reach of about EUR 486 million over the next five years.*
- *The annual Swedish market for new wooden residential multi-storey buildings is estimated around EUR 0.93 billion in the coming five years.*
- *There are no private equity type investment vehicles yet that would also focus on wood building construction and operation.*
- *The "green" building certification metrics do not yet pay enough attention to carbon, especially embodied carbon where wood performs well as construction material.*

5.1 Real Estate Investment and Green Buildings

There are a several ways of investing in green building. However, what is meant by green or sustainable real estate is not yet clearly defined, and even the emergence of various sustainability-related standards has not brought adequate clarity because of their multitude (see chapter 4.2). The following investment vehicles are used; none of them yet really mainstreamed to support large-scale investment to tackle climate concerns in the building sector:

- Direct finance with focus on green investments (debt, equity);
- Public-private partnerships;
- Green labelled property bonds;
- Real estate funds offering opportunity to invest in sustainable/green buildings; and
- Retail banking: green residential mortgages.

Institutional investors and commercial banks are most important in terms of investment potential. Public-private partnerships are also common and have been applied in Finland. In the US, there are real estate investment trusts (REITs), both in the public and private sectors, that are aiming at positive social, economic and environmental impacts through investing in sustainable real estate.

Real estate is a large and well-established long-term investment asset class for institutional investors and commercial banks. Mobilizing institutional investors is essential to accelerate the uptake of green building practices. Institutional investors - pension funds, insurance companies, sovereign wealth funds, hedge funds, and mutual funds - hold and estimated USD 100 trillion in assets of which 8-10 percent comprise real estate investments. Commercial banks are also a major source of financing for real estate through construction finance, mortgages, and home improvement loans. In 2019, the value of private equity investment in global real estate markets totalled a record USD 1.8 trillion (EUR 1.57 trillion). Out of that, as of today, still only a small share is explicitly targeted at green building investments, but the share is growing.

Following the recognition of the construction sector as a major global source of GHG emissions and consumer of energy, real estate investment is emerging as an avenue to address climate change concerns and sustainable energy use. Real estate investment investors are at the forefront of these changes and likely better positioned to deal with impending regulatory risks concerning energy efficiency of buildings or their carbon footprint, and other sustainability requirements.

Investors are paying more attention to sustainability issues in the building sector as part of "green" investing mandates that relate to environmental, social and governance (ESG) policies. This is reflected mainly in increasing attention to "green issues", such as climate mitigation, as part of the ESG, and to a lesser extent to creating dedicated investment vehicles for investing in green building. Credit Suisse Real Estate Fund Green Property is an example of a private equity fund of a major global bank that focuses on sustainable construction.

Building a portfolio of certified green buildings provides an opportunity for banks to increase their liquidity, develop new capital markets products, and expand their access to lower-cost capital, and for institutional investors to put their capital in green assets.

Low-carbon buildings are one of the eight sectors accepted for the use of proceeds under the Green Bond Taxonomy. By including low-carbon buildings in the lists of project types eligible for such financing, governments can enable a project pipeline in the sector without directly targeting it. Green bonds tap into international resources to leverage a wider investor base, such as pension funds, sovereign wealth funds, and insurance companies, and can potentially reduce the cost of borrowing for the issuer. The Low Carbon Buildings Criteria set out what building assets are eligible for certification under the Climate Bonds Standard. They are divided into three different types: Commercial Buildings, Residential Buildings, and Upgrade Projects. Energy rating schemes and energy labelling schemes are leveraged as emission performance proxies. Many of the building project criteria for Green Climate Bonds are based on the "green" building rating systems, such as Building Research Establishment Environmental Assessment Method (BREEAM), Green Star and LEED (see chapter 4.2).

The green investments and green metrics in the real estate sector, until more recently, have focused largely on energy efficiency as an environmental criterion. The business case for reducing embodied carbon is poorly understood, making the resourcing needed to conduct LCA and implement reduction measures difficult to justify. Wood buildings do not understandably feature separately in these investment vehicles, where the focus is on functions and impacts related to material conservation and resource efficiency, water efficiency/saving, and chemical emissions/substances that pose a risk to human health and environment and recycling, in addition to energy efficiency irrespective of the type of building. The focus on operational energy efficiency and the resulting reduction in greenhouse-gas emissions aligns with what large real estate funds and commercial banks consider to be the most material characteristics for their green real estate portfolios. However, focusing on this alone disregards the other benefits related to embodied carbon in building along the life-cycle.

The research has found a positive or neutral correlation between sustainable real estate investing and returns. At the same time, research also indicates that pursuing green investment goals can sometimes compromise return and financial performance because of higher investment and operating costs. However, technological development and scale are reducing rapidly the differences in construction. For example in Sweden, the costs of sustainable wooden multi-storey buildings are already at level, and even lower than the costs of concrete frame construction. In Finland, the unit construction costs of multi-storey wood buildings have been merging towards those of concrete buildings.

As part of the Q3 2020 RICS Global Commercial Property Monitor, respondents were questions on how preferences have changed for green buildings in the past year, and the impact on rents and prices. The survey found that occupier interest for green buildings has risen; across Europe, more than half of participants noted an increase in interest for buildings with green certifications; more than one-third of contributors believed that green buildings receive a rent premium over comparable non-green buildings; in Europe, 45% of participants noted that green-certified buildings are subject to a price premium.

In the future, property investors and financial managers may be driven to consider green real estate, including sustainable wooden buildings, in the portfolio because environmental regulations may require construction of green, low-carbon buildings as the industry standard. For example, embodied carbon may be integrated more systematically into building codes or regulated "carbon-budgets" are set for all new buildings, which would favour wood as a construction material.

Also in the post-Covid-19 world, the importance of the environmental qualities of a property, including air quality, creating a feeling of closeness to nature, and the wellbeing of its occupants, are likely to become more important as metrics to be used in impact investing in the real estate sector.

5.2 Standards, Certification and Metrics to Enable Green Building Market Growth

Standardised metrics and clear reporting requirements are essential to catalyse investment in green buildings at scale. Investors in sustainable/green buildings prefer having the buildings in the portfolio certified as “green” under one of the internationally recognised certification standards, or an approved national standard. The demand for third-party certification (based e.g., on LEED, BREEAM) is increasing in the construction industry and real estate investment. One of the most important reasons for certification is that it provides an independent verification and quality assurance related to sustainability performance by a recognised third-party (Box 6).

Box 6 Standards and Rating Systems for Green, Sustainable Buildings

Leadership in Energy and Environmental Design (LEED):

- Green building rating and certification system through independent third-party verification
- Performance in sustainable sites, water efficiency, energy & atmosphere, materials & resources
- indoor environmental quality, locations & linkages, awareness & education, innovation in design. A climate calculation of the building is also a requirement.
- There are different levels of certification LEED Platinum being the highest followed by LEED Gold

Building Research Establishment Environmental Assessment Method (BREEAM):

- Green building rating and certification system through on-site independent third-party verification.
- performance in: energy, health & well-being, transport, water, materials, waste, land use & ecology, management, pollution. BREEAM takes account of the production phase to some extent and also considers the environmental impact of the construction materials’ production from a life-cycle perspective.

EDGE (Excellence in Design for Greater Efficiencies, developed by IFC))

- A universal standard and a certification system for residential and commercial buildings with focus on emerging markets.
- Assessment areas include energy, water, materials

Green Globes Certification (a Green Building initiative):

- Third-party environmental assessment and certification for New construction; Existing Buildings; Sustainable Interiors
- Earn points in: Energy, Indoor Environment, Site, Water, Resources, Emissions, Project/Environmental Management
- It only takes account of energy consumption during the period that the building is in use.

Passive House:

- A climate-specific passive building standard and certification system; US focus.
- Focal areas: air tightness requirement, source energy limit, space conditioning criteria

The Nordic Swan Ecolabel (the official ecolabel of the Nordic countries, established by the Nordic Council of Ministers):

- For new buildings and renovation and focuses mostly on the construction process. Strict material requirements, banning substances that pose a risk to human health and environment while enabling the materials to be reused according to the principles of circular economy.

Miljöbyggnad (Eco-building, a Swedish system, developed by the Sweden Green Building Council):

- Can be used for new or existing buildings. The system uses different indicators for the building’s energy consumption, indoor environment, and documentation of materials with control of hazardous substances. In the newer versions it includes a requirement for a climate calculation for the materials used in the building.

Energy Performance Certificate (Under the European Energy Performance in Buildings Directive):

- An instrument to enhance the energy performance of buildings. Mandatory.

As can be seen in Box 6, the used standards and rating systems are not specific enough when it comes to carbon impact assessment, and especially dealing with carbon emissions, or embodied carbon following the LCA. However, given the emerging policy directions and regulations favouring low-carbon development, it is possible that these standards will be modified, e.g., by giving more weight (points) to low-carbon construction, including embodied carbon and standardised use of LCA, and introducing minimum requirements.

BREEAM and LEED and are among the most influential international rating systems. Energy Performance Certificates are also used; in fact, they are mandatory within EU and are incorporated under BREEAM and LEED. In Finland, LEED and BREEAM dominate, followed by a national RTS environmental classification and the Nordic Swan Ecolabel. The recently completed wooden Supercell office building in Helsinki has applied for the highest LEED Platinum certification (which it will likely receive). In Sweden, the national Miljöbygnad is the market leader, followed by BREEAM, Green Building and LEED.

Many countries have also developed their own systems, often based on BREEAM and LEED, with modifications to reflect local priorities and market conditions. To date 85 countries have adopted national or local building certification programs. The main reason for the large variety of certification schemes is context sensitivity in different countries and cultures.

5.3 Market Prospects and Investment Vehicles for Wood Construction in Europe

Wood construction is projected to increase in Europe. The great potential to increase wood construction, especially large/tall buildings, is based on several factors, such as an increase in the European CLT and LVL capacity, development of new modular construction technology, adjusted fire codes enabling construction of tall buildings, gradual strengthening of construction and design knowledge and capacity, and the policy push towards environmentally friendly, low-carbon buildings. The national wood building programs and the roadmaps to promote low-carbon development in the construction stimulate wood building construction. Increasingly, local-level zonation identifies areas for wood construction. For example, in Finnoo in Espoo, Finland, an area was zoned just for multi-storey wood residential buildings.

The greatest potential for increasing the use wood, and especially engineered wood products, is provided by multi-storey residential and office as well as public buildings because the uptake of timber systems in large buildings is currently very low. A recent Finnish doctoral dissertation (Hurmekoski 2017) concluded that the Nordic and several Central European countries, as well as the UK, would have the highest potential to increase wood construction (Table 5).

Table 5 Market Potential of Wood Construction in Selected Regions in Europe

Region	Northern Europe	Central Europe and the UK	Other Western Europe	Southern and Eastern Europe
Market Potential by 2030	**High**	**Intermediate**	**Low to intermediate**	**Low**
Countries	Finland Norway Sweden	Austria Northern Italy Southern Germany Switzerland The UK	France Ireland The Netherlands Northern Germany	The Czech Republic Hungary Poland Southern Italy Spain

Source: Hurmekoski 2017

Market Prospects for Multi-storey Wood Buildings in Europe

Estimating the European market for wood construction, e.g., for the next five or ten years, is challenging because it depends on the overall development of construction volume, that is often cyclical reflecting gross domestic product (GDP) development and also interest rates. Demographics, including household development, changes in the degree of urbanisation, government policies and programs, regulations, incentives, and various factors influencing the cost of wood construction, all affect markets prospects for construction of multi-storey wood buildings. There are also major variations for the potential for wood construction within Europe and, unfortunately, the quality of statistics needed for estimating the market development vary country by country. In many countries, there are no statistics on the use of wood construction; one of the challenges is caused by hybrid buildings. Further, the impact of COVID-19 on the construction volume brings a lot of uncertainty; the short-term impact is negative on average within EUR with significant variation between countries.

Given these constraints, the following estimates need to be regarded as indicative. Detailed country studies are needed to develop more reliable estimates. The focus here is on multi-storey residential, office and public buildings, because that is where most of the growth potential is for making use of low-carbon construction materials and modular technology and generating opportunities "green" real estate investment.

The total EU market is estimated at around EUR 5 billion for multi-storey residential, office and public building construction with an average annual growth rate of 8% (EUR 450-650 million on average) in 2021-2030. In five years, the market is estimated at EUR 7.5 billion and by 2030 the market is estimated to exceed EUR 10 billion.

The annual market growth rate can easily be higher, close to EUR 600 million a year on average, because construction of wood buildings, and use of materials such as CLT and LVL, and modular, off-site construction technology, can follow the S-curve. The share of wood construction of total multi-storey buildings in Europe is still very small on average, and growth rates can be high in the coming 1-2 decades.

The Finnish Market for Multi-storey Wood Buildings

In Finland, the greatest potential for *increasing* the use of wood can be found in the construction of multi-storey residential and office buildings and in public buildings (offices, various type of halls, educational facilities, day care and elderly case centers). After Spain, Finland is the country with the highest percentage of apartment buildings in Europe: about 46% of all residences in Finland are in apartment buildings. More than half of annual new residential construction (about 30,000 to 40,000 residences/year) is currently in apartment buildings. CLT and LVL volumetric element solutions dominate at present in new wood apartment buildings.

In principle, there is potential to even build shopping centers of wood. These buildings can be mainly wooden buildings but there is also great potential in hybrid construction (wood, concrete, steel), exemplified by the famous Oodi Library in Helsinki or the new the Supercell head office.

In Finland, the annual market of new wooden multi-frame residential buildings is estimated around EUR 486 million, and EUR 2.4 billion in five years,

In chapter 4.2, projections by Granlund Oy for wood construction were presented in which the base scenario aimed at 35% market share for new wood-frame multi-storey buildings by 2035, 65% share for public building by 2035, and 50% for office and commercial buildings by 2035. It is possible to reach these targets in Finland. However, in this report a different approach with a focus on the next five years (2021-2026) based on the Ministry of Environment database[1] on existing building plans was adopted. In December 2019, the plans for wood-frame multi-storey residential buildings amounted to 11 070 apartments equalling a floor area of 772 488 m^2 (on average 70 m^2/apartment). In October 2020, the plans covered in total 11 720 apartments which would equal about 820 400 m^2.

If 80% of these plans were implemented in five years, the share of wooden multi-storey residential buildings of total new construction would more than double at around 12-14%, and thus be very close to where Sweden is now (see Figure 7). Annual construction volume would be around 131 264 m^2, corresponding to 1 875 apartments and 31 apartment buildings (assuming 60 apartments per building). To put this into perspective, as of autumn 2020, there were 106 wooden multi-storey buildings in Finland. An average construction cost of EUR 3 700 per m^2 was assumed.

[1] Suomalainen puukerrostalohankekanta. Suunnitteilla ja rakenteilla olevat suomalaiset puukerrostalohankkeet. 2019.

In Sweden, the annual market of new wood multi-storey residential buildings is estimated at around EUR 0.93 billion. This estimate is based on the 2019 construction statistics indicating that 4 034 apartments in wooden multi-storey buildings were constructed in 2019 corresponding to 282 380 m^2 and average construction cost of EUR 3 300/m^2.

In Germany, the current market at the annual market of new wood multi-storey residential buildings is estimated at around EUR 1.1 billion. This is based on the statistics indicating around 2% market share for wood-frame buildings of total residential multi-storey construction in 2019.

In the UK, the current market of new wood multi-storey residential buildings is estimated at around EUR 0.9 billion.

Potential for Monetising Carbon Benefits of Wood Construction

Mainstreamed opportunities to cash in, or monetise, the incremental carbon storage service, provided by construction of e.g., multi-storey wood buildings, do not yet exist. Carbon credits could be a revenue stream for green building investment but there are no common rules and protocols for carbon accounting across both forests and buildings which poses a risk for double counting.

It is likely that this service value will be reflected through the environmental rating schemes, such as LEED and BREEAM, and possible willingness to pay a little bit more for construction of a green building, but then the carbon service would be just part of the overall “environmental package”. However, there are initiatives such as those by Puro.earth (see *https://puro.earth/*). Puro.earth has created a new kind of carbon offset, the CO2 Removal Certificate, based on carbon net-negative products. CO2 Removal Certificates (CORC) are digital tradable carbon assets that confirm 1 tonne of CO2 has been absorbed and stored in a carbon net-negative product. CORCs are issued for only the extra carbon absorbed after a third-party verification of the product - e.g., CLT panels used in construction - has proven that it is carbon net-negative from cradle-to-gate. At present, CORCs are issued for three CO2 removal methods, and one of them is Wooden Building Elements. DNV GL has provided auditing services. However, this scheme is so new that it is not possible to assess the potential for its scalability.

How to Invest in Green Construction and Wood Buildings in Finland?

There are no specific investment vehicles yet in Finland targeted at green/sustainable construction or investing solely in climate change-related commercial projects. In fact, there are no dedicated funds in Finland that would target sustainable/green investments in the country. This reflects that fact that impact investing is still quite young in Finland. SITRA (The Finnish Innovation Fund) and the Finnish National Impact Investing Advisory Board are promoting the development of an impact investing ecosystem to address this issue.

A very recent development related to impact investment concerns one of the main Finnish banks, OP, that has launched the OP Finnfund Global Impact Fund I. It raised EUR 76 million in June 2020 in the first round of funding, but it does not invest in Finland.

However, there are some recent examples of commercial banks and private equity investors investing in the construction of wood buildings:

- NREP, one of the biggest real estate investors in the Nordic countries, entered into a frame agreement with the Finnish building construction company Lehto Asunnot Oy on the construction of wooden residential buildings with approximately 300 rental apartments in the cities of Espoo and Turku. These are low-carbon buildings making use of wood’s carbon storage capability to reduce carbon footprint and of geothermal heating as energy solution to reduce climate impact during operational period.
- The building construction company Lehto Asunnot and Taaleri Vuokrakoti fund (Taaleri is a Finnish financial services company) have agreed to build a wooden multi-storey residential building in Kirkkonummi which will contribute to low-carbon development due to the use of wood as raw material and relying on geothermal heating.
- The Finnish bank OP has a special fund OP-Palvelukiinteistöt that has invested in 36 wooden day-care centers and elderly care buildings.

- Further, OP Vuokratuotto Fund has invested in multi-storey wood buildings in Tampere, Turku, Hämeenlinna and Helsinki. In Hämeenlinna, the Fund invested in building student apartments, cooperating with the Finnish Puukerrostalot Oy and the largest European construction company specialised in wooden multi-storey buildings, Swedish Lindbäcks Bygg Ab.

In Finland, despite the existence of various channels to invest in wood buildings, there is room for financial institutions to develop financial products and services targeting wood construction (multi-storey residential houses, office buildings and commercial infrastructure) to support climate change mitigation efforts. It is essential to accelerate this type of investments to help with expanding the housing capacity while contributing to the national targets for low-carbon construction sector. These buildings need to meet the highest international environmental/sustainability standards consistent, e.g., with the requirements of LEED or BREEAM. This means, in principle, adopting a LCA approach in the design and paying attention both to embodied carbon and carbon emissions during operations as well as energy efficiency – including ideally production of own energy, e.g., through thermal heating - throughout the life cycle. One needs to be prepared that, maybe by 2025, all new buildings in Finland will have regulated “carbon-budgets”.

The public sector can support the decarbonisation of the construction sector through developing supportive national policies and programs as well as targets for green, low-carbon building development, including enabling regulations and codes that treat various construction materials fairly and set clear standards and frameworks for low-carbon building construction. Public sector can also play a major role through supporting education and research and development related to use of wood in construction, and developing low-carbon construction sector, in general. At the local level, zonation of areas for construction of just wooden residential multi-storey buildings is an important means of promoting low-carbon construction and enhancing opportunities for investing in the construction of wood buildings.

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