



Nordregio

NORDREGIO WORKING PAPER 2023:2

Innovation Dynamics in Wood Construction in Sweden and Finland

Alberto Giacometti & Hilma Salonen

Table of contents

Preface	3
Introduction	5
Technological innovation	9
Historical overview of industrial development and technological innovation in wood construction	13
a. Prior to 1994: emergence of prefab modular and mass timber	13
b. Post 1994 onwards: A new market for Multi-Storey Wood Construction (MSWC)	15
Institutional & public sector innovation	22
Legislation	22
Policy tools	31
Governance and soft approaches	33
Systems perspective to innovation in wood construction	36
Conclusions: the roles of actors	42
References	45
About this publication	49



Photo: Gabriel Giacometti

Preface

The rapid developments in wood-construction and the huge expectation built around the potential of 'greening' the construction sector by replacing concrete and steel with wood provide our empirical ground to study the drivers of innovation.

This publication provides the results of a case study on the construction sector transformation process triggered by the emergence of wood-based construction in Sweden and Finland, particularly of multi-storey buildings. We especially aim at reconstructing the micro-processes leading to innovations and breakthroughs in the market. Interviews with a variety of stakeholders have contributed to a reconstruction of a historical overview of some of the main events and drivers decisive for the industry's development, from far past industrial and policy-driven steppingstones to more recent developments. In our analysis, we zoom into the more granular microprocesses that become evident when examining the interactions between actors within and beyond their formal roles.

The publication is one of the outcomes of the project titled "[Systems perspectives on Green Innovation \(GRINGO\)](#)" that explores the bottlenecks to innovation and the green transition from a systemic perspective. The project focuses on uncovering the links between agency and innovation, particularly regarding the role of different 'change agents' in driving transition processes.

The previous step of the project consisted on exploring key concepts, their application, and their theoretical foundations within innovation and policy traditions. It concluded in the [Discussion Paper: A conceptual review on the systems perspectives on green innovation](#), published in September 2022. The paper touches upon the academic discussion that has developed around the drivers of innovation. The debate breaks away from the simplistic structure-agency divide, which attributes causality either to structures (rules-of-the-game) or agency (actors), to consider the complex interplay between actors, formal and informal institutions, and contextual conditions determining innovation. These

theoretical perspectives then guided the second step of the project, an empirical study on a selection of topical green transition cases, particularly regarding sectoral or industrial transformation.

The project is implemented within the [Nordic Thematic Group for Green, Innovative and Resilient Regions 2021-2024](#).



Photo: Kotryna Juskaite

Introduction

Wood is certainly one of the oldest building materials and has been a key resource in the Nordic countries over time. As Andersson (2020 p57) puts it: "employing renewable, locally sourced, and strong yet light material, wooden houses have dominated the single-family housing market in Sweden for centuries". In Sweden, the oldest surviving wooden buildings date from the 13th century (Swedish Wood, access: 02/10/2022). Given this context, it may seem odd to speak today of innovation, and 'green innovation' particularly, in the construction sector by means of wood. However, as a consequence of devastating fires in cities throughout Europe in the 1700'-1800's, wood buildings became considered a hazard leading to a ban on multi-storey wood buildings. Finland (under the Russian Empire) banned wooden buildings of more than two storeys in 1856 (Suikkari 2007) and Sweden in 1874 (Swedish Wood, access: 02/10/2022). After more than a century of prohibition, multi-storey wood buildings are experiencing a renaissance. The negative association to fire-hazards gives way to a positive outlook of wood as the means for 'greening' the construction sector.

The construction and life cycle of buildings are associated with 39% of global carbon emissions, of which about a third comes from the production of building materials (Rasmussen et al. 2021). In addition, the industry uses significant amounts of energy, mineral and metal resources during the construction and use phases of buildings (ibid.). Reducing the carbon footprint of the sector has, therefore, gained considerable attention from policymakers. Novel regulations are being introduced to trigger and accelerate the transition of the industry towards low-impact practices and solutions. From January 2022, new regulations in Sweden and Finland require 'climate declarations' from all new buildings, which is a stepping stone towards setting limit values on carbon emissions for new construction projects. These challenges represent an opportunity for the forest

industry, as building in wood significantly cuts the carbon footprint of construction. Assuming that wood is harvested from sustainably managed forests (an increasingly contested issue), wood construction appears as the most sustainable option in Nordic countries. Processing and producing wooden building materials use less energy-intensive industrial processes than extraction and production processes of cement and steel. Additionally, wood stores carbon for the lifetime of the building, and possibly beyond, since wood elements are easily reusable and recyclable. After two decades of slowly creating a market for multi-storey wood construction (MSWC) in the Nordic countries, it is now expected to rapidly expand and capture a sizeable market share over the coming years.

In 1994-95, Sweden introduced the new Building Codes (BBR), which effectively annulled any restrictions on wood construction (Smart City Sweden 2020). This reform to the legislation, however, was not particularly motivated by the opportunities offered by wood materials in construction. Instead, it was part of a process of harmonisation of legislation required for accession to the EU (Andersson, 2020, p61). The sudden shift of the 'rules of the game' generated high expectations within the forest and wood industries (Interviewee 1). The development, however, was slower than expected. After a century of building with cement and steel, a wide knowledge and skills gap surrounding the construction of tall wood buildings, as well as the need for a more profound cultural and systemic change. However, the experience gained over the last 25 years by the wood industry and building companies, as well as engineers, architects, planners, regulators, academia, banks, and insurance companies, has allowed this 'sub-sector' to find a place in the market, gradually increasing its market share to ca. 20% today, and set a solid ground for rapid expansion over the years to come (Interviewees 1, 2, 8). National and sub-national authorities have also played a substantial role in promoting wood building by setting bold ambitions, mobilising stakeholders and funding, and most importantly by taking risks and leading by example in the construction of public buildings and apartment blocks. Moreover, timing has favoured wood construction, first by several decades of a sustained urbanisation process and by the increased social focus on environmental sustainability since the early 2000s (Interviewees 1, 2, 3). In line with this trend, wood strategies have an increasing focus on climate goals, capitalising on the momentum.

In Finland, key promoters of wood construction also began to mobilise after the country's accession to the EU **in 1995**. However, restrictions on the height of MSWC and fire safety were lifted gradually. The government cycles have initiated a number of policy and research programmes from 1986 onwards to support knowledge building on material science and structural engineering. The national strategies also set ambitious goals for increasing wood construction, and a number of municipalities took the lead by building schools and other public facilities, generating demand as well as built experience to incentivise private investments. While government programmes generated substantial knowledge and expectations from the forest and wood industries, market creation has faced substantial resistance. Negative perceptions, regulatory barriers, and the dominance of the concrete industry have limited MSWC to a marginal position

until recently. Compared to Sweden, construction processes have remained underdeveloped, more inefficient, and thus expensive. Timing has also been less favourable in Finland compared to Sweden, as urbanisation and demographic trends have been stagnating in the last few decades. These factors have considerably hampered the efforts of wood construction actors to gain a foothold in the market despite political support, which has remained constant for over three decades. Under these difficult conditions, the role of a few 'champions' has been key, such as the various tools and methods that bigger cities have wielded to motivate and even force constructors to choose wood. Today, the market share of MSWC remains at around 5% but is expected to accelerate (Paavola 2019).

Regulation and policy push or technological innovation were not the sole agents behind the rise of modern high-standard buildings in wood. Making way for wood construction in the market has required the creation of a new 'sub-industry' and business ecosystem. These efforts have led to an overhaul of the whole system, from changing business practices, spatial planning systems, and industrial processes to changing the organisation of the construction sector, their supply chains, business models, and financial schemes, as well as promoting an overall cultural change. Collaboration across multiple public, academic, and private actors from different sectors has been pivotal in shifting cultural values, setting common goals and new policy incentives, and building trust. Trust has been the basic condition enabling the industry to make large and risky investments.

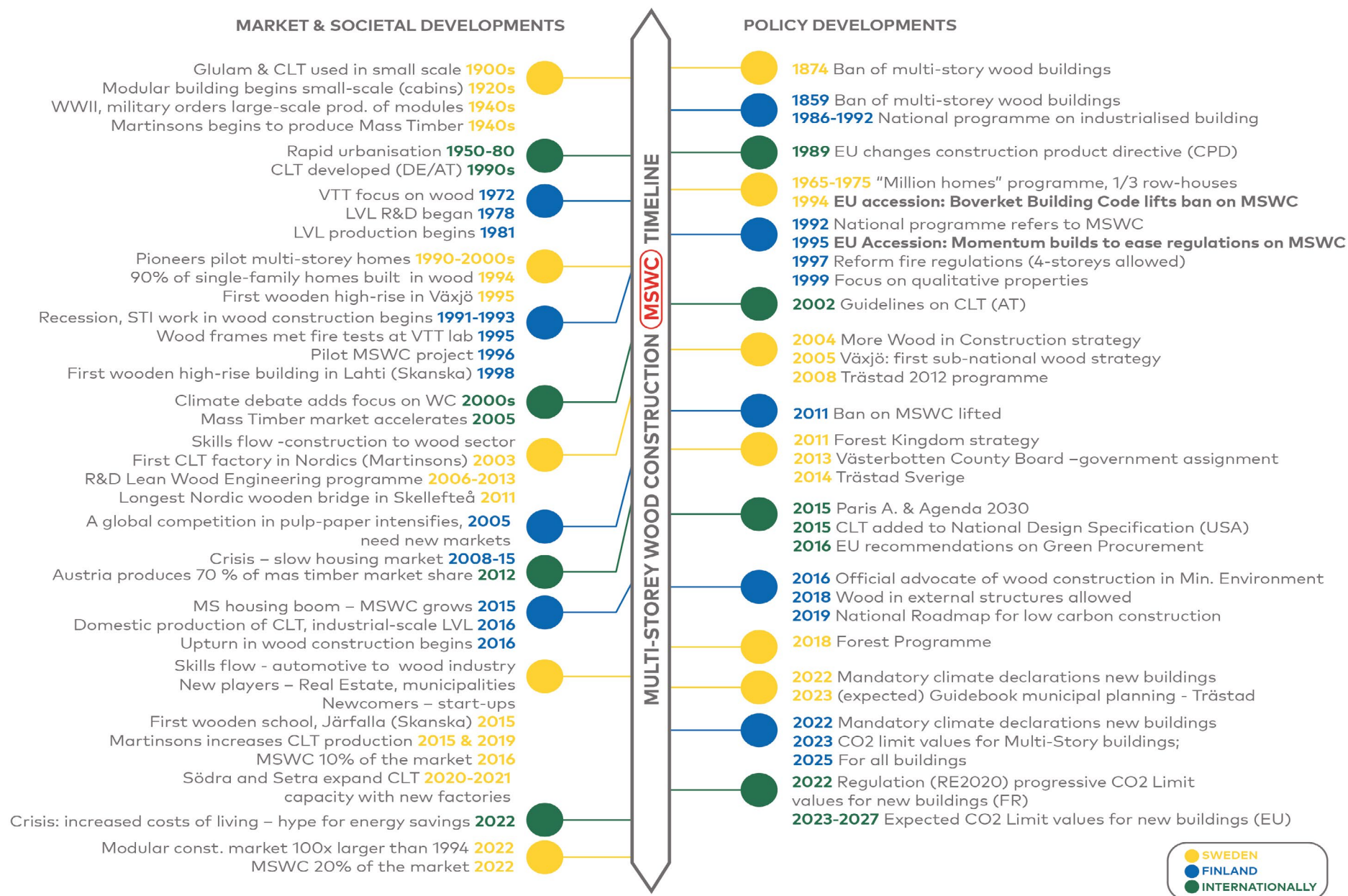


Figure 1: Timeline Multi-storey wood construction (MSWC) – key industry and policy developments. Source: authors.



Photo: Gabriel Giacometti

Technological innovation

Technological innovation in modern wood construction derives from material science and structural engineering, from the testing the properties of different types of materials and wood products in relation to stability, vibrations, fire-safety, acoustics, energy efficiency, and so forth. Moreover, technical, and technological innovations also include industrial processes, architecture and design tools, transport, and supply chain innovations. Significant efforts have centred around developing building systems and the industrialisation of construction (The Lean construction method). As a result of the 'green agenda', increased focus has centred, in recent years, around new ways of designing for assembly and disassembly, considering the life cycle of buildings, their transformation over time, and their 'end-of-life'. We focus more specifically on building systems and industrialisation processes as follows.

There are different construction techniques and systems used to build with wood. Important differences have to do with the degree of prefabrication and the types of wooden products and combinations of materials used. Conventional construction generally implies work done mostly onsite, the use of traditional materials, and a low level of industrialisation. In many high-income economies, however, conventional construction also implies the use of industrialised or prefabricated building elements. Prefabricated (or prefab) elements, such as frames, columns, and slabs, are produced in a factory and assembled onsite. To varying degrees, most buildings in industrialised economies today build portions of their structures in a factory setting. While wood is a traditional construction material, multi-storey wood buildings still represent an outlier. Innovation in wood construction has pushed the industrialisation process forward, with both modular systems to produce prefab volumes, and wood-engineered products to create prefab frames and other building elements. According to Nord (2008), there are roughly three levels or methods of prefabrication in the production of multi-story wood buildings: 1) onsite construction using pre-cut components, 2) assembly onsite using prefab timber elements, and 3) assembly onsite using prefab and pre-assembled timber volumes (Figure 2).

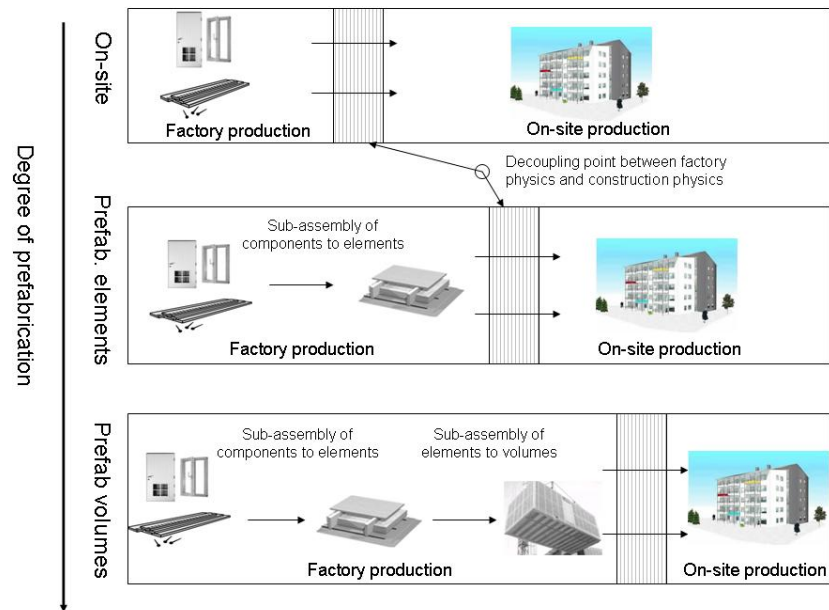


Figure 2: Construction methods in relation to the degree of prefabrication. Source: Nord (2008).

In Sweden, about 97% of all multi-storey buildings with a wooden frame have been completely or partially prefabricated by 2020 (Swedish Forest Agency 2020). In modular systems, most components are prefabricated offsite and assembled onsite to produce volumes, resembling human-scale LEGO. Prefab modular construction can reach the level of manufacturing ready-made rooms or sections of apartments, including electrical installations, heating, plumbing, and air-conditioning systems in a factory setting (Manninen 2014). Other systems use prefab frames and building elements similar to conventional construction but replace concrete-steel elements with structural wood engineered products or mass timber such as glue-laminated timber (Glulam), cross-laminated timber (CLT), and laminated veneer lumber (LVL). (Refer to **Info Box 1** for definitions).

Different building systems and wood products have their own uses, advantages, and disadvantages. Wood is a light, structural material, with a low or negative carbon footprint, and is vastly available in the Nordic countries. Modular construction in wood moves most of the construction work offsite, to a factory setting. Systematising the work in a factory setting has numerous advantages. It provides a dry and predictable working environment, while minimising the possible problems of climate or accessibility to the site; it reduces disturbances to the public around the construction site; it allows for a different organisation and better coordination of the work with fewer sub-contractors, as more workers are employed at the factory instead of providing services onsite; and it radically cuts the time of work onsite, making it possible to assemble a high-rise building in the span of a few months. All these benefits also result in lower costs of production/construction. Because of these attractive advantages, the growth of modular wood construction as an industry is now comparable to electric cars in speed, growing from € 20 million to almost € 100 million in a few years (Interviewee 2). A commonly known disadvantage is that prefab modules limit

the flexibility of architectural design (Interviewees 1, 6; Brege et al. 2013). However, this limitation may be less related to the technical possibilities offered by modular systems and more to transport restrictions (as lorries cannot carry units of any shape and size), or to decisions made at the design stage before considering the option of using modular systems, rendering it too late in the process (as modules can potentially be built in any shape). In any case, modular construction is a top alternative when speed and cost efficiency are prioritised over architectural expression: for instance, when municipalities or regional authorities wish to rapidly increase hospital beds, elderly care homes, schools, or affordable homes. Modular construction comes handy in delivering high volumes efficiently in a competitive and cost-efficient way (Interviewee 2).

Furthermore, the introduction of engineered wood products has added versatility in the use of timber in construction, making it possible to build larger structures, which are light, structurally sound, and energy efficient, among other positive qualities. One expert view is that the introduction of CLT represents a radical innovation in the sense that it has enabled the construction of large wooden buildings. At the same time, CLT allows designs similar to conventional buildings, requiring no major deviations in the design process (Interviewees 1, 11), making the innovation decisively less disruptive.

As the market develops, the focus is shifting from building exclusively with wood-base systems to also incorporating opportunities for hybrid construction systems and materials: mixed wood products, or wood with steel, concrete, recycled materials, or new innovative materials. For instance, non-bearing walls can use lighter, material and space-efficient alternatives instead of structural materials such as CLT. It is also possible to combine building systems, as in the case of the SARA Cultural Centre in Skellefteå, which was built using a glulam frame combined with CLT modules in the hotel units.

Finally, several experts coincide that besides the development of construction systems, the industrialisation of wood construction represents a breakthrough, making it possible to build in scale, reach higher production volumes and move from a niche market to compete with conventional construction. By applying the principles of 'lean construction' and 'lean manufacturing', industries have optimised the workflow in production facilities enabling them to cut costs and produce in higher volumes. Lean manufacturing or 'lean production' is a methodology or practice first applied in the post-war by the Japanese automobile company, Toyota, aiming at increasing productivity via continuous improvements in the production system. It maximises value by minimising 'waste' both in terms of material resources and superfluous processes, activities, work, and time spent in the production system. Lean construction uses these principles to make the process of building considerably more efficient, saving valuable time. The main principle of lean construction is to reduce all work phases that do not produce added value to the customer, for instance, decreasing waiting time at the construction site (Rakennuslehti 2016).

Info box 1: Terms and concepts

Engineered wood products or Mass timber: "are made by glueing wood, veneers, panels, strands or fibres together to form pillars, elements or modules that can be used in building family houses, multi-storey buildings or other constructs, such as bridges" (Manninen 2014). CLT, Glulam, and LVL are all different types of engineered wood products.

Glued laminated timber (glulam): "Glued laminated timber comprised of multiple layers of timber bonded together with an adhesive to form structural beams." (Ramage et al., 2017)

Cross Laminated Timber (CLT): "Cross-laminated timber comprised of multiple layers of wood panel bonded together, [crosswise], perpendicular to one another with an adhesive to form a uniform wood panel with structural properties." (Ramage et al., 2017). "The result is a construction element that is transversely rigid and durable in relation to its low weight. It enables large spans and rational methods for rapid assembly" (Martinsons 2015).

Laminated Veneer Lumber (LVL): "Laminated veneer lumber comprised of multiple layers of thin wood bonded together with an adhesive to form structural elements, such as beams." (Ramage et al., 2017).

Prefabricated (prefab) construction: A construction technique in which building components, elements or volumes are manufactured offsite in a factory setting and then transported and assembled onsite. The degree of prefabrication varies between building systems, from the manufacture of components only, to the offsite assembly of more complex elements and volumes. Modular construction allows for the most advanced for of prefabrication.

Modular construction: A form of prefabricated building system in which a building is manufactured offsite, in repeated sections called modules or volumes. Modules usually consist of the ready-made ceiling, walls, and floor resembling human-scale LEGO, and can include even all internal components including electrical installations, heating, plumbing, and air-conditioning systems. A structural frame is usually built by using pillars and beams or tile-type flatpacks. (Puuinfo.fi).

Flat pack house: is a prefab house constructed out of pre-cut components produced offsite usually made as a timber frame system. Differently from modular houses, these are transported disassembled and do not include painting, plumbing and fittings.

Lean manufacturing or 'lean production': is a methodology or practice first applied in the post-war by the Japanese automobile company, Toyota, aiming at increasing productivity via continuous improvements in the production system. It maximises value by minimising 'wastes' both material and in terms of superfluous processes, activities, work, and time spent in the production system.



Photo: Gabriel Giacometti

Historical overview of industrial development and technological innovation in wood construction

a. Prior to 1994: emergence of prefab modular and mass timber

The technological innovation process that has made it possible to build multi-storey buildings in wood cannot be presented as a linear train of events. Technological innovation did not begin with legislation change or the adoption of a national strategy. The old legacy of woodworking and industrialisation of the wood industry, particularly in Northern Europe, has accumulated a vast amount of knowledge and skills and resulted in advanced technologies in terms of machinery, building systems, products, and applications. The century-long prohibition on multi-storey wood buildings in Sweden, Finland and most other countries, did not prevent companies from building wooden single-family houses and larger structures, such as barns or event halls. Indeed, by the early 2000s, 80 % of all single-family houses in the Nordic countries were made of wood (Manninen 2014), with 90% in Sweden (Näringsdepartementet, 2004). Engineered wood products or mass timber were also utilised in construction, although on a small scale. Nevertheless, the degree of industrialisation and technological development varied significantly between countries and companies, as well as the type of technologies, materials and building systems used. In addition, the experience of building MSWC was mostly inexistent.

Modular construction

In Sweden, modular construction in wood can be traced back to the 1920s, when a handful of companies started producing modules, mostly as temporary structures (Interviewee 2). Then in the 1940s, modular construction received a sudden boost as a by-product of World War II, with the military seeking for a quick solution to accommodate a large number of soldiers mobilised to guard the national borders. Companies that had so far developed modular construction

were urgently requested to mass produce modules to build barracks. This enabled companies to generate the skills and industrial capacity to reach high volumes, which helped them roll out prefab construction into the market in the 1950s with the rapid post-war urbanisation process. A second, even more considerable push for modular construction came with the Million Homes programme (Miljonprogrammet in Swedish), with which the Swedish government set itself the goal of building one million homes within ten years (1965-1975). Although this programme is mostly famous for high-rise concrete apartment blocks, around one-third of its houses were single-family homes. Another third were low-rise buildings, many of which were built in wood with prefab modules or 'flatpacks' (Interviewee 2). Continuous urbanisation and expanding markets for holiday homes reaffirmed the development of modular construction in the following decades. The scale of these developments enabled companies to build up capacity and industrialise the production of modular construction. These constituted key preconditions for the development of multi-storey modular buildings after 1994, when regulatory barriers were lifted.

In pre-war Finland, prefabricated building mainly emerged from sporadic experimentation, and industrialisation in construction happened later than in other sectors. During the reconstruction period after the war and the following urbanisation process, there was an urgent need to build more homes. Combined with strengthened industrialisation following the Finnish war reparations to the Soviet Union, these developments led to a surge in prefabricated building from the 1950s onwards. The first experiments in scaling up with the help of prefab techniques happened in the frame of industrial production buildings, followed by office buildings from the 1970s onwards. In apartment buildings, the construction sector has been more reluctant to do expensive experiments, and development has been slower. The breakthrough in prefabricated apartment buildings finally happened due to changes in zoning laws in 1959, which allowed for planning whole residential areas instead of singular blocks, creating favourable conditions for mass production. The 1970s saw a record number of residential homes built in Finland as urbanisation accelerated. From the 1950s onwards, the conventional construction industry also re-organised internally and conducted significant work for creating common standards and reinforcing their strong hold in the market. (SBK säätö 2009)

Engineered wood products (mass timber)

By the time Sweden, Finland and other EU member countries began to change their building codes, making it possible to build MSWC, engineered wood products were already produced industrially albeit on a small scale. After a few, arguably unsuccessful, attempts to introduce engineered wood products, they regained interest in the 1990s, first in Germany and Austria and then in Sweden, Norway and Finland. The renaissance of mass timber began in Germany and Austria and focused mainly on single-family homes, but soon apartment buildings became the main target in the Nordic Countries. According to an expert opinion, the failed initial attempt to introduce engineered wood products in the 1980s may be connected to the business model which targeted lighthouse

projects, such as event halls and stadiums, instead of regular housing (Interviewee 2). Martinsons represents an exception in Sweden as it produced mass timber for the housing market, possibly explaining why it survived while many other companies stopped producing mass timber until recently (Interviewee 2).

b. Post 1994 onwards: A new market for Multi-Storey Wood Construction (MSWC)

Context by 1994: Baseline for MSWC

The long history of the wood industry in Sweden and Finland gave a strong basis for enabling the development of MSWC. However, because of the century-long ban, initially there was nearly no experience in building large multi-storey buildings in wood. Prior to the legislative reforms in 1994, there was nearly no research on using wood as framing material in larger buildings (Nord 2008). The lack of experience pertained to all aspects of construction, from structural engineering and building systems, to achieving standards and regulations for fire safety, ventilation, acoustics, and energy efficiency in MSWC. There was limited knowledge and skilled labour across relevant sectors. There was also no built stock for reference for new buildings and for banks and insurance companies to assess risks. Despite these challenges, the ban lift on MSWC, paired with a policy push for developing wood construction and the decisive steps taken within the wood industry, all led to a rapid process of experimentation, knowledge creation, and technological innovation, followed by a process of systematisation and industrialisation.

Piloting and experimentation

As wood re-emerged as a possible material for large-scale constructions, a handful of pioneering companies began an intensive process of experimentation, piloting, and testing building systems, both modular and traditional systems but using structural wood engineered products or mass timber, i.e. Glulam, CLT, and LVL. During this **first phase of development**, the companies involved were mostly large with a pre-existing industrial capacity and the financial resources to invest in R&D. In Sweden, Moelven and Lindbäcks, among other companies producing prefabricated modular houses in wood, invested in knowledge and capacities to develop building systems for high buildings (Interviewee 2). The companies' experience in producing modules for single-family homes on an industrial scale was a considerable asset for developing modules for multi-storey buildings. Although 90% of prefabricated homes were built of wood in the 1990s, most of them were not modular but 'flat pack houses,' which are constructed out of pre-cut components, transported onsite disassembled, and do not include painting, plumbing and fittings. Building multi-storey homes from modules and the extremely efficient assembly processes was therefore a true gamechanger, and the market of modular MSWC grew from 2,5 million EUR in 1994 to a hundredfold more, coming up to c. 125 million EUR (Interviewee 2). However, different companies underwent distinct development paths. While Moelven has targeted

private customers and offered a wide range of choices, other companies, such as Boklok, the Skanska-IKEA joint venture, apply a more fixed model comparable to IKEA furniture, with only a narrow selection of options (Interviewee 2). Martinsons', instead, invested in developing building systems using mass timber frames in multi-storey buildings. This process mobilised a first wave of skilled labour into the wood industry, coming mainly from the construction industry. One interviewee is himself an example of this trend as he was called from his position in the construction sector to work at Moelven to help them develop building systems (Interviewee 2).



Photo: Alberto Giacometti

In Sweden, universities and institutes lacked the infrastructure and programmes for conducting research surrounding wood construction before 1994 (Nord 2008). After discussions with the forest industry, academia and policymakers, significant R&D was mobilised in a 'triple-helix' set-up. A major research programme was launched in 1996 aiming at increasing the basic knowledge of using timber in larger structures (ibid.) One project stemming from this programme was the Cross-Laminated-Timber Consortia (Massivträkonsortiet) bringing together representatives from the wood industry, building contractors, consultants and universities. Massivträkonsortiet delivered many successful results for knowledge creation around product properties, how to develop timber frame systems, and solutions around fire-safety, noise reduction and moisture. A number of prototype buildings erected and handbooks for using timber in larger structures also resulted from this programme. As a participant in this consortium, Martinsons "learnt more about process flow and production management for structural elements" (Nord 2008).

Later on, the Lean Wood Engineering programme (2006-2009) was launched, aiming at developing industrialised timber frame construction and industrial wood components and systems. With a budget of 36m SEK, co-funded in equal parts by Vinnova, Sweden's Innovation Agency, industry partners, and three universities (Linköping University, Luleå University of Technology, and Lund University), the programme aimed at increasing academia-industry cooperation with academic, industry-related, and financial goals. The programme also involved several PhD candidates that developed their research around most topical issues at hand, carrying out calculations and tests to design structurally sound frames, or to examine fire-safety, acoustics and sound insulation, or moisture. Among the expected results were an increase in related research and education, more cooperation between companies, and increased R&D financing. The 'research' component of the programme mainly centred around developing business and processes, with less focus products, whereas the 'development' part of the programme mainly explored industrial wood construction and manufacturing (Kunskapsförmedlingen 2022; Stehn 2022). Later, similar projects on smaller scale, for example, one launched at the Luleå Technical University, have involved many of the same companies and aimed for increased cooperation between academia and industry (Träbyggnadskansliet 2014).

Industrialisation of wood construction: from onsite to a factory-setting

Once the handful of pioneer companies had succeeded in developing construction systems for multi-storey buildings, a **second wave of development** began as industries focused more actively on the industrialisation of wood construction by applying lean manufacturing principles to systematise the workflow. In this process, companies invested in the infrastructure and equipment needed for scaling up production. A second wave of skilled labour made its way into the sector, this time coming from the automotive industry (Interviewee 2). Experience in the production line of automobiles was particularly useful, argues one expert, as for example there are many similarities in the way trucks and modules are assembled.

According to several experts, the **industrialisation** of wood construction is perhaps the most important **innovation**, enabling the emerging 'sub-sector' to move from the piloting-phase and niche market to mass-production and capture a sizable slice of the construction market. Industrialisation also means moving parts of the construction process offsite, to the factory. Offsite construction offers many benefits. As one informant puts it: "offsite construction can lower the construction time and costs, but also change the habits and processes that were less efficient" (Interviewee 1). According to one expert:

"while the technical innovations were developed over a hundred years ago, streamlining the production, the workflow and lean production, to get the volumes needed for a full building offsite, has changed the game" (Interviewee 2).

However, the degree of industrialisation of construction varies depending on the

choice of building systems. For instance, mass timber frames (beams, columns, slabs) mimic conventional building frames in concrete and steel, and thus requires no major changes in the architectural design. Modular construction, instead, requires changing the whole building process from architecture and design, to building and assembling, moving a major part of the work offsite (Interviewee 1).

Despite the many benefits of going offsite and increasingly systematising the construction process into factory work, the progress has been slow as the learning process and designing new systems and protocols has required much time, effort, and investment (Interviewee 1). The transition also implies new players entering 'the game' challenging the established practices and business relations built over time. Moving offsite radically changes the organisation of work in construction projects, which has led to shifts in the actors involved or the contractual conditions in which they are involved, as well as new collaborations networks, and trust relations (Interviewee 1).

Emergence of a new market: a bumpy road

Despite the initial hype generated from legislative changes and the strategies developed at national and sub-national levels, the market for MSWC did not immediately experience the desired boom. The goals of reaching 30% of all multi-level construction to be built in wood frames in a decade-time in Sweden (2005 strategy) (Lindblad 2020), and 10% in Finland 2015 (2011 programme) (Laapotti 2020) proved too optimistic and underestimated the weight of the structural inertia. Today, 15-20% of new multi-storey buildings are built in wood in Sweden (Interviewees 2, 3) and less than 5% in Finland (but 40% of public buildings) (Paavola 2019; Laapotti 2020). The slower market growth than expected generally points to the strength of a well-established construction sector based on concrete-and-steel, with large investments made in infrastructure for production, and accumulated skills, experience and networks that operate around the established ways. The status quo is also reinforced by clients' familiarity with concrete construction, including municipalities and other public actors which are responsible for regulating and setting the standards for new developments. However, high expectations also seem to stem from a simplified understanding of industrial transformations, whereas change takes time and requires systemic thinking.

Industrial MSWC has slowly made its way to transcend the structural inertia in the construction sector, but penetrating the market has required new forms of financing, risk-taking and applying different business models. In early stages, pioneer companies circumvented traditional actors including contractors and banks instead of challenging them directly. Lindbäcks, with origins in the construction sector, was the first company to build multistorey residential wood buildings using volumes (modular construction) in 1994 (Nord 2008). Having a real estate sister company, Lindbäcks was able to create demand for itself (interviewee 2).

Moelven instead, with nearly a century of experience building modular single-family homes. First in Norway, then both in Norway and Sweden, developed its

own capacities and production system to build multi-story buildings in wood, likewise circumventing construction companies reluctant to take the risk in new solutions. Similarly, Derome AB, dating from 1946 is active along the solid wood value chain and developed a lightweight framing system A-hus and modular construction. The company has built many projects through its own developing and real estate company (Nord 2008).

Martinsons, initiated in 1939 with a sawmill and later began producing glulam. After a dormant period in the mass timber market, Martinsons developed to becoming a supplier of building elements and wood housing company (Nord 2008). Following regulation changes in 1995, Martinsons gradually entered the building industry and created its own construction company, Martinsons Byggsystem AB, taking the whole building process in its own hands. Martinsons went as far as to providing everything needed on the construction site from consulting to plumbing (Interviewee 2). More recently, Martinsons was acquired by Holm, a forestry company, bringing further together parts of the supply chain under a single company. Holm now controls the source of the material, the processing, the fabrication of mass-timber products and building elements and, for many projects, also the design and construction of new buildings (Interviewee 9).

In addition, several companies with origins in the forestry industry, such as Stora Enso, Setra, Södra, amongst others, began the production of timber products and created their own building systems moving prefabrication of building elements further down the supply-chain. For example, Södra Building System developed a truss system that is offered to contractors (Bengtsson, 2003 in Nord 2008).

As wood construction continues to expand its market share, circumventing established contractors is becoming less necessary as many of them have now gained experience in wood building. Instead, the wood industry is working closer to construction companies (Interviewee 2). On the contrary, the many conservative construction companies that have resisted to change are now feeling the pressure and see the need to build own capacities to build in wood. This trend is likely to accelerate as new regulations are on their way to set limit values on emissions of new buildings, making wood a favourable choice (Interviewee 5). Going forward, construction companies will inevitably become part of a larger transformative process by which changes in parts of the system will impact several other parts including the relations with other companies and subcontractors (Interviewee 1).

Market development of engineered wood products (mass timber)

A number of companies began producing glulam in the post-war period in Sweden, of which three still stand today: Martinsons, Setra, and glulam of Sweden AB (Suomen liimapuuyhdistys ry and Puuinfo Oy 2014). However, the market for glulam and mass timber products experienced decline and stagnation

in the 1980s and 1990s. Then the market for mass timber products started to boom in the early 2000s, mainly in Austria and in Central Europe, but also in the UK and France and to a smaller degree in Canada and Australia (Manninen 2014). Within a decade, the demand for glulam nearly doubled to ca. three million cubic meters in Europe (globally about 5 mil m³), most of which was produced in Germany, Austria, and Finland (Manninen 2014). The production of CLT began in the early 2000s (Manninen 2014). Stora Enso, the Swedish-Finnish company, established their CLT factories in Austria, whereas Martinsons established the first CLT factory in the Nordic Countries in Sweden in 2003. Soon after, Södra and Setra built their own CLT factories in Sweden. Despite the economic crisis in 2008 and shaky housing markets, the consumption of CLT was not reduced. As demand continued to increase, new factories were established in different countries, e.g. Monnet Seve in France (2013), Cross Lam Kuhmo Ltd in Finland (2014), amongst others. The production of LVL in Finland began in 1981 but took decades to scale up, with notable investments targeted towards MSWC construction only since 2016. The material properties of LVL make it a competitive option for mid-high apartment buildings and office buildings (Lazarevic et al. 2020). Today, there are also several factories in the Baltic countries producing mass timber and modular houses targeting the Nordic market.

Economy and market conditions

The efficient industrialisation process has succeeded in creating a viable market in Sweden to the point that building a multi-storey apartment building from wood can be today c. 15-20% less expensive than using concrete and steel (Laapotti 2020). In Finland, where the market is not yet self-reliant, the situation is often the opposite (ibid.). To make the processes as efficient in Finland as in Sweden so that the price of wood construction would drop, the demand would have to be stronger. However, since there is a lack of expert knowledge and process management know-how of wood construction, the price remains high, keeping the demand low. This in essence is the vicious cycle plaguing the sector in Finland, stemming from the century-long lead that the concrete industry has in the competition, and the resulting tight relations with construction companies (Interviewee 1, Laapotti 2020). The rigidity of the existing system also means that the flow of the process must remain more or less similar in every project even if the product is different. For this reason, customer must have made the decision to build with wood early enough so that the process can be adapted to incorporate it. If the decision is made during the first stage, the process is very efficient but it is difficult for the industry to make a good offer based on plans that have already been made.

Broader market conditions have hit a growing market as well especially in Finland during the 2000s. Notably, the 2008 economic crisis and subsequent prolonged economic downturn slowed the housing market in Finland and previously growing markets export for glulam, for example (Manninen 2014). CLT continued to increase production despite of the crisis, however it was still produced at a much smaller scale than glulam (Manninen 2014). Sweden's housing market was not

significantly affected during the financial crisis in 2008, and on the contrary the housing deficit dragging from previous decades in combination with a growing population meant that demand continued to increase. In Finland, a slower pace of construction and declining population in many regions has also played a role in the slower pace of development of wood construction.

Beyond the role of private actors

The emergence of multi-story wood construction could not have been possible by companies alone challenging the status quo, taking risks, and circumventing tradition industries. There are other important drivers of change, notably the national government, first in its power as regulator and changing the rules of the game, but also as an enabler, by setting strategies and assigning funding to support the development of the sector. Moreover, municipalities have played a major role in pushing the market to adopt wood as a possible alternative but also by itself taking the lead and risks in building public buildings and publicly financed housing blocks. The following chapter focuses on the role of the state, sub-national authorities and institutional innovation.



Photo: Gabriel Giacometti

Institutional & public sector innovation

Legislation

The first, and crucial, institutional innovations enabling MSWC were the changes in legislation that previously prohibited the use of wood products in buildings taller than two storeys. In 1989, the EU implemented a Construction Products Directive (CPD) aiming at removing any technical barriers to trade in construction products between member states in line with the EU common market (Railio 2014; Elspecta AB). The rationale was to move from material-based standards to function-based, which ended up eliminating barriers for wood construction even though not specifically supporting it. Regardless of the material used in construction, the new legislation decrees that buildings have to meet the standards regarding fire, energy efficiency, acoustics, accessibility and other 'functions.' The directive, which has since then been replaced with a more harmonised regulatory framework, however, left much room for interpretation and freedom of implementation to individual member states. Nevertheless, it served as an important milestone for regulatory changes made at national level during the following years. (Interviewees 1, 3, 6)

With Sweden's accession to the EU in 1994, the Swedish National Board of Housing, Building and Planning (Boverket) evaluated the Swedish rules and regulations and decided to harmonise them with the EU CPD. The new regulations became effective with the first issue of the Building Codes of Boverket (BBR), in which detailed technical requirements were substituted by requirements based on function of the end-product. The regulation would set 'the minimum function or property required but not in detail how to accomplish the function' (Nord 2008). As a side effect, the use of wood was no longer inhibited in larger structures as long as the 'functions' were met. For instance, no matter the material used, buildings are required to stand a fire for 90-120 minutes before collapsing (Interviewee 1, Andersson, 2020 p61). In practice, this represented a total lift of the ban on MSWC in Sweden.

In Finland, legislative changes occurred more gradually. Following the first legislative ban against two-storey wooden houses with fireplaces in mid-1800s, fire regulations continued to restrain wood construction in apartment buildings in Finland, even after the accession to the EU. However, increased global competition persuaded policymakers to revise established regulations in favour for new approaches (Tolppanen et al. 2013). Still, a hybrid model emerged as new function-based regulation did not fully replace material-based restrictions. The fire safety regulation was reformed over the years, eventually allowing for a wider selection of building materials in increasingly higher multi-storey buildings. First in 2011, 5-8 storey buildings were allowed (Paavola 2019). Then, in 2018, simplifications to the regulation were made allowing unprotected wood in interior and exterior surfaces of residential buildings of up to 16 storeys (using automatic fire extinguishers) (Lazarevic et al. 2020).

Climate declarations and limit values on carbon emissions

Fast forwarding time onto current times, a new policy push is underway to reduce the environmental footprint of the construction sector, which indirectly favours wood construction. From January 2022, in Sweden, all new construction projects of over 100 m² must conduct a climate declaration (with exceptions). The Swedish National Board of Housing (Boverket) defines:

"A climate declaration describes the building's climate impact, as calculated based on the greenhouse gas emissions from the construction stage. The construction stage comprises the extraction of raw materials, manufacture of construction products, work at the construction site and transport". (Boverket Website: Access 31-10-2022)

The Swedish government assigned Boverket the task of developing and managing a climate regulation database and registry to assist reaching climate goals in construction. It targets the climate impact at the construction stage, i.e. relating to building permits of new buildings. During the first phase, Boverket's tasks included developing an open database to calculate the climate impact of buildings and a registry to be used when regulation is in operation (both launched in January 2022). While on this task, they also focused on spreading information and developed a plan for future actions to take the whole life cycle of a building better into consideration for further climate impact reduction. Next steps include setting limit values for emissions in new building, latest in 2027 (possibly already in 2025) and proposed to be lowered in 2035 and 2043 (Boverket Website: Access 31-10-2022; OneClick 2022). In addition to climate declaration, there are several voluntary certification schemes in use in Sweden (OneClick 2022).

The realisation that the work toward optimising energy efficiency of new buildings soon reaches its maximum level of efficiency and minimal level of emissions, led regulators in Finland to shift their focus on reviewing emissions during the whole life-cycle of a building, starting with public procurement. Finland followed the European Commission's decision to publish voluntary recommendations regarding green procurement in the construction of offices in 2016 (The Ministry of Environment 2022). In 2017, the Ministry of Environment

began the work for measuring the climate impact of buildings to lay the groundwork for future limit values of emissions. The national roadmap of low carbon construction in 2019 suggested a climate declaration for multi-storey buildings from 2020 onwards, followed by setting limit values for multi-storey buildings from 2023 and for all buildings from 2025 (Bionova 2017). The final version of the roadmap until 2030 will be published alongside with the new zoning and building act of 2024. Voluntary measures currently in place include a policy for assessing public buildings (acknowledging life-cycle emissions), possible regional agendas of cities and municipalities, and international and national sustainability certifications for buildings. All these efforts align with the national goal of making Finland carbon neutral by 2035, with some cities like Helsinki reaching this aim already by 2030 (OneClick 2022; The Ministry of Environment 2022).

Even before climate declaration regulations begin imposing limit values in Sweden and Finland, carbon footprint of buildings may be used by real estate companies as a marketing tool, one expert foresees (Interviewee 1). A parallel can be made with the energy declarations requirement for new buildings introduced in the early 2000s in Sweden, which soon after led real estate companies to add the energy consumption profile of new apartments into their marketing strategies. Also, as national actors are developing procurement criteria for low-carbon buildings and low-carbon roadmaps, these initiatives are likely to support wood construction as well, as wood is given the status of a low-carbon building material (Lazarevic 2020). In addition, climate declarations are in turn likely to feed into broader regulatory pressure to consider climate impact of buildings as the EU has shown interest in implementing the Nordic climate declaration model across Europe (Interviewee 14).

One point of discussion surrounding the upcoming regulations setting limit values for carbon emissions of new buildings, is the methodology and criteria used for calculating carbon emissions. It is debated whether these should consider only the construction phase or the whole life-cycle of buildings. The debate seems to be leaning towards considering the life cycle of buildings, including the production, construction stages, use, end-of-life stages, and possibly the potential uses of buildings and building elements beyond their end-of-life (See Figure 3). Life Cycle Assessments (LCA) represent new opportunities for wood construction as it requires significantly less energy intensive processes, it captures carbon in the material, and being a lighter material requires much less transport compared to heavy materials i.e. cement and steel, as well as it is an easily recyclable material. (Rasmussen et al. 2021). Another debated issue is whether to include pre-existing structures built in a plot of land in LCAs. Indeed, avoiding demolitions and repurposing old buildings normally results in significantly lower emissions as opposed to building new, even 'sustainable' buildings. However, more for economic than technical reasons, companies tend to prefer demolishing. (Interviewee 11).

Product stage			Construction process stage		Use stage					End of Life stage				Benefits and loads beyond the system boundary
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	C1	C2	C3	C4	D
Raw material supply	Transport	Manufacturing	Transport	Construction-installation process	Use	Maintenance	Repair	Replacement	Refurbishment	De-construction demolition	Transport	Waste processing	Disposal	Reuse-Recovery-Recycling-potential
					Operational energy use				B6					
					Operational water use				B7					

Figure 3: Life Cycle Stages: production, construction process, use, end-of-life phases, and the potential uses beyond the system boundary. Source: Rasmussen et al. (2021).

National strategies in Sweden

Sweden's first policy effort to directly promote wood construction kick-started with the government decision in 2002 to appoint a national coordinator to steer the groundwork for formulating a national strategy. This work resulted in the 'More Wood in Construction' (Mer trä i byggandet) strategy adopted in 2005 (Näringsdepartementet, 2004). The strategy set the target of 30% of all new buildings to use wood-frames within the following 10–15 years (Lindblad 2020). This target is still difficult to reach today, yet, it represented an important first step to generate discussion and mobilise public and private actors. The strategy was the result of analyses of the state of the art, trends, and emerging needs of the forestry and construction sectors (Interviewee 1). Discussions were held within the industry, ministries, and municipalities, revealing important structural transformations in construction and systemic barriers on the way for introducing more wood-products into the sector. This groundwork also led to selecting Skellefteå (in Västerbotten), Växjö (in Småland), and Falun (in Dalarna) as frontrunner municipalities leading the implementation of the strategy (Interviewee 1). Together with local authorities, a list of short-term and long-term objectives and activities were formulated, including research and pilot projects in collaboration with the industry for increasing knowledge production to better inform the sector. The Ministry of Industry also appointed a coordinator to implement the activities listed. (Interviewee 1).



Photo: Alberto Giacometti

The first strategy in 2005 was mainly framed from a regional development perspective based on the industrial legacy and growth potential in several regions of Sweden (Interviewee 1). The strategy also introduced the notion of wood construction as a political climate strategy (Andersson 2020). However, the link to environmental sustainability was initially weak and only gained prominence in later versions of the national strategy. In 2011, the first strategy was replaced with a broader national strategy titled: 'Forest Kingdom – with values for the world', launched by the Minister for Rural Affairs. "The 'Forest Kingdom' strategy aimed at increasing the economic development potential of rural areas while also seeking new export markets for the timber industry" (Andersson, 2020, p61). Furthermore, the Forest strategy of 2018 has also boosted wood construction for its part, although its main focus is on bioeconomy and developing forests as a national resource (Interviewee 8). Updates to the national strategy have tapped on the political commitments made in the Paris Agreement and UN Agenda 2030 to frame it more directly as a climate strategy (Interviewee 1). More generally, forest sector representatives experience a shift in Swedish forest and wood policies from considering the needs of industries to emphasise climate issues (Interviewee 6). More recent policy discussions, instead, have centred also on social sustainability (Interviewee 1). This coincides with the introduction of the 'Just Green Transition' concept in the EU Green Deal, which brings to the fore the discussion of social justice or 'fairness' to industrial transformations. The shifting foci in the different generations of the strategy also denotes the political landscape in the times when they were formulated and the priority areas of the ruling governments. The strategy of 2011, heavily concentrated on industrial development, was formulated by the right-leaning government, whereas the strategy in 2018, which emphasised nature conservation, was formulated by the Social Democrats-Environmental Party coalition (Interviewee 8).

Efforts started with the implementation of the strategy were then followed up in 2008 by a national three-year programme in the form of a project called 'Trästad 2012' (Wood City 2012). Trästad was launched in 2008 first as a four-year programme and has since continued in cycles with slightly different emphases (Interviewee 8). Trästad 2012 involved seventeen municipalities and was aimed at fostering large-scale production of MSWC. During the programme, participating municipalities developed their own projects and activities focusing on themes relevant to their contexts. More specifically, municipalities in North Sweden focused on CO₂ calculations and climatic stress in the construction phase; municipalities in mid-Sweden focused on cost-efficiency via standardization; municipalities in the Southeast focused on environmental targets; and municipalities in the Southwest focused on ways to increase the use wood in public construction, particularly in improving competences on public procurement (NTT WoodNet 2012). The experience gaps across municipalities, and diverse focus of this programme proved to be particularly useful for knowledge transfer.

Building on the efforts of the Trästad 2012 programme, Trästad Sverige has since continued as a platform and a node for several projects, bringing together over 60 members from municipalities, relevant ministries, architects and construction companies. When the association began to receive funding from the state (since 2016) its organisation shifted from being led by municipal politicians to being managed by a professional hired for the task. Currently, the main objective of networking activities is supporting regions and municipalities in compiling a wood-building strategy by assisting them in operating related regulations and legislation via the digital platform Wood First. In addition to spreading knowledge, the platform facilitates dialogue about wood building, involving various stakeholders and enabling them to have direct contact e.g. with the Ministry of Housing (currently within the Ministry of Industry), or between industry actors and municipalities (Interviewees 6, 8). In addition, within the Wood First project, a roadmap was developed for Swedish politicians and municipal planners that wish to better support wood construction and may require both strategic and practical guidance with tasks such as planning or public procurement. The project also aims supporting wood construction by linking it with other aims or sole urgent needs, for example, utilising wood in social housing is an effective way to produce comfortable homes quickly, or to add more living space on top of or around existing buildings (Interviewee 6).

Coinciding with the establishment of Trästad, the County Administrative Board of Västerbotten received a mandate in 2013 from the government to collaborate with interested municipalities to develop wood construction in a cost-effective way, build knowledge and engage other more municipalities to the cause to contribute to the Swedish national climate goals. With the governor acting as chair of Trästad, Västerbotten has remained in the lead of the platform since (Trästad Sverige web).

Furthermore, the Swedish government has supported wood construction via more indirect means as well, as by enabling construction firms to develop skills and increase capacity in modular construction. State intervention, such as the

order to mass produce barracks during the Second World War by using wooden modules, and to urgently increase the housing stock with the Million Homes programme in 1965-1975 with the help of prefabricated construction, have been major catalyst factors setting the scene for MSWC to develop (Interviewee 2). Today, the government claims impartiality at least on the surface, so publicly procured buildings remain 'material-neutral' in-line with function-based regulations. However, state authorities have continued supporting the development of forestry and wood sectors, not least by financing Trästad Sverige, as well as investing in R&D. The influence of climate policies is more indirect but significant, via new legislation aiming at cutting carbon emissions from the construction sector. Wood construction advocates are also critical to considering state impartiality given that the Swedish government is a shareholder of Cementa, the main cement industry in Sweden, LKAB, the iron-ore mining company, and SSAB, steel company, as well as having the national interest of supporting the forest industry, a large economic sector (Interviewee 6). Furthermore, having banned MSWC for over a century required state intervention, in the form of policy support, mobilising stakeholders, and funding, to build the market 'from scratch'.

National strategies in Finland

Since mid-1980s, Finland has paid close attention to wood construction in the form of government strategies and support programmes (Saarnivaara 1998). The first cycles of governmental funding focused on different aspects, from technological innovation to architecture and urban planning, aiming at solving issues that would render wood a riskier alternative (Siikanen 2008; Metsä Group 2013; Tolppanen 2017). Coinciding with strategic governmental programs, the state, the forest industry and the Finnish Funding Agency for Technology and Innovation (now Business Finland) took upon funding efforts in the fields of science, technology, and innovation partly as a support measure following the heavy recession of the early 1990s. Although all these efforts produced practical knowledge and led to regulatory reforms, these R&D programmes were not enough to establish a market base for actors in wood construction.

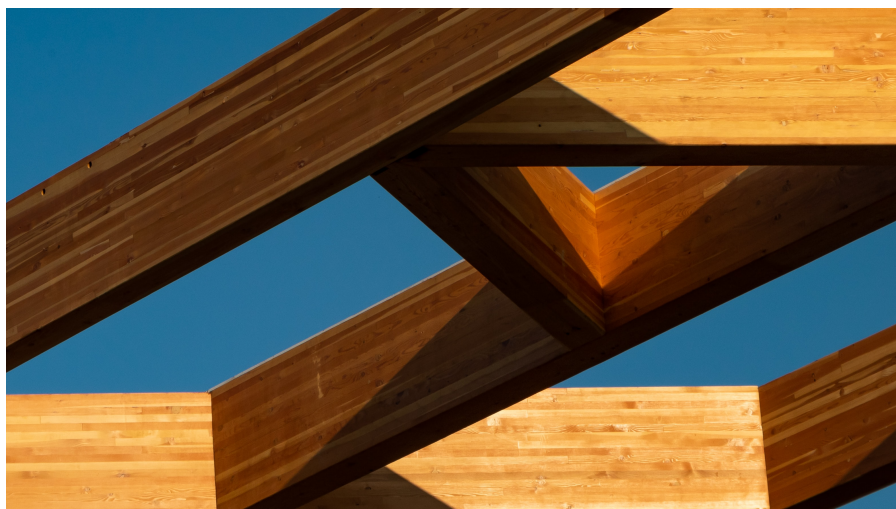


Photo: Greg Rosenke / Unsplash.com

In the 2000s, the use of wood found more possibilities also in other official strategies related to housing. In response to the EU-wide trend, Finnish national strategies have put more emphasis on qualitative properties in housing instead of increasing quantity only (Purdy 2010). Additionally, global competition in paper and pulp markets added pressure on forestry actors to find new outlets for their products, leading to increased policy support for developing wood construction as an opportunity for the forestry sector. Following this logic, strategic programmes drafted in the 2000s have considered the increasing market share of MSWC and set the aim of capturing 10% of new housing stock built by 2015 (compared to 1% in 2011). However, initial policy targets in Finland, as in the Swedish case, have proved too ambitious, with little activity in the industry between 2011 and 2014. Despite, government programmes produced an influx of theoretical knowledge and led to regulatory reforms (even the appointment of an official advocate of wood construction in the Ministry of the Environment), as well as the implementation of several pilot projects, the market share have narrowly expanded (Lazarevic et al. 2020; Saarnivaara 2022). According to one opinion, research programmes have overly focused on material properties, thus neglecting broader subjects such as processes and solutions related to wood construction (Interviewee 13). Still, Finnish wood construction programmes have had most impact in terms of shifting attitudes, building regulations, and municipal planning processes. Despite meagre results, strategic work remains ambitious with the latest wood building strategy aiming at capturing 20% of the market share by 2025, and 50% share in publicly procured buildings (Paavola 2019).

The strategic and R&D work done within these governmental programmes has paved the way for wood construction by creating more favourable conditions in terms of increasing knowledge and improving the regulatory framework. However, this work does not suffice to address the deeper structural barriers stemming from the resistance from strong lobby groups of established actors and their close ties with the construction sector. As long as development of the sector relies on pilot projects, wood construction continues to suffer from higher costs due to inefficiency and insufficient skills. Finland's first wooden high-rise apartment building in Lahti, 1998, remained also the only one for a long while because its high cost did not encourage the construction company Skanska to continue with timber building (Mölsä 2021). Therefore, barriers are difficult to be surpassed by policy-making.

Subnational strategies in Sweden

The groundwork done for drafting the national wood construction strategy in Sweden quickly mobilised regional and municipal authorities in drafting their own ones (Interviewee 1). ' *More Wood in Construction 2005 and Väckjö*' was the first municipal strategy (Interviewee 1). Updates to the strategy (2013) have set the target for Väckjö Municipality and the city's municipal companies of 25% of all new buildings to use wood frames, and 50% by 2020 (Väckjö Municipality 2013). Similarly, regional strategies were designed to support the local industry in key forestry regions such as Småland, Västerbotten, and Dalarna. In addition to

wood construction strategies, several municipalities now have climate strategies setting goals for carbon neutrality, or they have joined the network of Swedish Climate Municipalities (Interviewee 7).

In Småland region, the municipal strategy of Växjö was aligned with the regional strategic (2012) goals related to Småland reaching a leader status among Europe's wood regions by 2020 (ibid.). Regional and municipal strategies anchored to the national strategy generated a domino effect causing cluster organisations, interest groups and private actors to get involved (Interviewee 1). Given the clear political stance, "construction companies in Växjö realised that to win projects and get a competitive advantage they needed learn to construct from wood" (Interviewee 1). As a result, wood construction industry has levelled up their competences and competition has increased, which is leading to increased innovations (Interviewees 1, 2). This, in turn, has led to private and public actors, jointly, "apply for money from European regional funds and research organisations to support their activities" (Interviewee 1).

However, it is notable that the practical and policy work leading to publishing a strategy often began much earlier than any official platforms or strategies were in place. In Växjö, for instance, wood building took off before the first wood construction strategy was adopted in Sweden, immediately coinciding with the lifting of the ban on MSWC. In 1994, Värendshus built a three-story house using wooden frames and shortly after in 1995, Sweden's first modern five-storey wood-frame building was built as an exemplary case in Växjö (Wälludden). The municipality also began working on related academic research and strengthening before adopting a timber building strategy. (Lindblad 2020; Tina Wik Arkitekter 2023).

In Skellefteå, the municipal strategy was only adopted in 2014, but intense work to foster wood construction started as early as the introduction of new national building codes. After a period of economic stagnation in the 1990s, which hit the forestry industry, the change in legislation was seen as a golden opportunity by the then chair of the municipal council, Lorentz Andersson (Interviewee 7). Without any formal strategy, the municipality took bold decisions by taking the lead in building the wooden apartment buildings in 1995 and the longest wooden structure bridge in 2011, followed by an even longer one in 2022 (Interviewee 7; LTU 2011; Byggvärlden 2022). The low threshold for collaboration between local actors facilitated the communication and quickly the forest industry and local authorities aligned their visions to incentivise industrial development. At the time, the focus was mainly on adding value to the forestry industry to generate economic activity to support local businesses and create new jobs. The municipality then began ordering wooden buildings from the early 2000s as well as to establish strategic lines of cooperation with research and academia, i.e. RISE, Luleå University of Technology and Umeå University, not the least by investing in a university campus for them to establish education and research in Skellefteå (Interviewee 7). The strategic work at the county level was then built on the work of proactive individuals and close links between public authorities and local businesses. The Västerbotten county has been on the forefront of

supporting wood construction since 2000s, when Lorentz Andersson was appointed as governor of the County Administrative Board and was given a special mandate from the government to act as chairman of the National Timber Construction Strategy. Emphasising the high importance of individuals in developing the market, Andersson was also titled a Knight of the Order of the Wood Market in 2008. Skellefteå's wood construction strategy was eventually published in 2014 to work in a more systematic manner and set a clear path for future development. This coincided with the broader societal focus on climate and sustainability goals, which then became a pillar of the wood industry agenda (Interviewees 7, 8; Skogsindustrierna 2008).

Furthermore, many of the municipalities originally involved in Trästad 2012 started planning for wood-based construction projects as early as 2006. Today, around 180 municipalities in Sweden have built tall wooden houses and the number is increasing with several large-scale projects involved. One example is Frostaliden in Skövde, where 150 wooden apartments are being built, several of which are six-storey buildings. Another example is Välle Broar in Växjö, which represents Sweden's largest continuous wooden project and where an entire district has been built in wood (Ekholm 2011). The first school built entirely on wood was erected also in Northern Sweden, Järfalla, by Skanska in 2015 (Woodnet 2014).

Policy tools

Beyond the work done at a strategic level, municipalities use more practical tools such as spatial planning, zoning, building permits, and public procurement to steer development. These tools managed at the municipal level have a significant potential to support wood construction, if wished (Interviewee 12). In the Swedish context, municipal plans are generally grounded on political decisions, a programme for housing development or general building plan, and occasionally take in suggestions proposed by developers (Lindblad 2020). Decisions are then executed by municipalities via 'procurement processes' or 'land allocation processes', which are the procedures municipalities often use to identify and select (via competition) suitable developers to engage on development projects (Lindblad 2020). Municipal plans, however, are often rigid and adapted slowly to changing conditions. At the same time, they have a significant potential in lifting barriers on the way of innovations by means of wood construction. One common barrier today are the way limits to building heights are stipulated in zoning regulations, generally using meters instead of counting the number of storeys. This appears to disfavour certain types of wood construction as wood beams and slabs are thicker than the equivalent in concrete adding height to the same number of storeys. In many cases this means that picking wood implies reducing one storey to the building. As developers generally try to maximise the gross area that can be sold, wood-based alternatives are left out if they see the economy of the project to be penalised. Updating municipal plans and zoning rules can, therefore, open considerable new market opportunities (Interviewee 2).

In addition, one more instrument often used by municipalities are 'land

development agreements'. The legislation gives municipalities a certain leeway to define more specific conditions and requirements for detailed planning based on its internal policy documents and targets (Lindblad 2020), for instance setting limit values for carbon emissions based on climate targets (Interviewee 6). Via land allocation agreements, municipalities can take advantage to favour wood construction. For instance, along with the work for formulating its strategy in 2005, Växjö municipality explicitly stated in its wood strategy that it will actively work with land allocation and land development agreements to increase the development of wood construction and as method to define new areas for wood construction, e.g., Torparängen. This is also mentioned to be the basis for discussions with developers and contractors who were willing to work with wood (Lindblad 2020). In Skellefteå, the city requires contractors to build an attractive and sustainable housing area, which values imply the use of wood (Interviewee 7). These implicit ways are used because the extent to which municipalities can favour wood construction is restricted by the Planning and Building Act in Sweden, which does not allow setting technical requirements for land development projects (Lindblad 2020), such as material specifications. These agreements are most commonly used when developing municipal land, as the owner can set conditions for selling or using the land.

In Finland, municipal planning has thus far been the most influential tool in supporting multi-storey wood construction, particularly to scale up production volumes and processes, leading to increasing experience. This has been useful in generating learning on better practices and solutions, enabling wood construction sector to access market advantages usually belonging to the concrete and steel industries. For example, Jyväskylä has taken initiative in creating zones for wood construction, then followed by Turku, Vantaa and more recently also Helsinki (Interviewee 12). Zoning can be an effective way for cities and municipalities to impact climate emissions, when they so wish. This can take the form of mandating assessing the carbon footprint of city-owned projects or having Life Cycle Assessment as requirement when conducting land sales competitions, as is done in Helsinki (OneClick 2022). Most importantly, the new procurement law of 2016 allowed Finnish municipalities and cities to use public procurement as a straight-forward way to support wood construction as they can state the use of wood as one criterion when calling for proposals. Another way is to refer to the carbon footprint of a building as a criterion in public procurement, which often leads to favouring wood as material (especially if the municipality already has a carbon neutrality strategy), granting the best plots for wood construction projects, or referring to emission reduction goals when granting building permits (Mölsä 2021; Ympäristöministeriö 2022b).

'Green procurement' is perhaps an even more powerful tool for steering development towards municipal interests. The term, green procurement simply refers to using public procurement with the specific intention of pushing forward the green agenda or environmental sustainability. Public procurement includes any purchases made by public authorities from buildings, services, to meals in public schools, hospitals, or care-homes. Again, while not being able to set technical requirements, municipalities set standards such as impact assessments

on climate, or weight to narrow down the possibilities for wood construction to be outcompeted in bidding processes. This instrument has been crucial in boosting the development of timber construction, where municipalities have favoured the construction of schools, sports and event halls, and municipally owned housing projects. For instance, Skellefteå municipality finances a significant share of all 'green financed' developments (Interviewee 6). Since 2016, Finnish municipalities have been able to make 'green investments' in environmentally friendly projects in the form of affordable loans or leases. Most of these projects have been schools or day-care centres made with wood (Puu-lehti 2017). By investing in timber construction, municipalities have helped to create a market by helping the industry to experiment, to learn, gain experience, stimulate the expansion of supply-chains, and very importantly by taking and sharing the risk.

Governance and soft approaches

Besides public policy tools, municipalities play an important role in day-to-day work coordinating the industry, research, civil society, and different actors to facilitate the implementation of new ideas and projects and to generate knowledge around different issues. Generally, the contractor is accountable for the risks involved in a construction project. Therefore, most companies will play safe and commit to deliver what they know how to do, and can more accurately calculate costs, time spent, and assess the risks. However, innovative projects, such as wood building, imply diving into unknown territory and taking higher risks. Building common ground and trust among key stakeholders generates the conditions needed to embark on new ventures. Carefully managing and sharing the 'ownership' of risks has been a key success factor in enabling more ground-breaking projects, such as the Sara Cultural Centre in Skellefteå (Interviewee 4).

Lindblad (2020) suggests that there is evidence of even more bold changes in municipal governance. In Växjö, the author notes that private, research and other actors have been more directly involved in the building planning process and proposed wood-building solutions. One specific example is the formal cooperation established between Växjö municipality with developers and university partners around land allocation agreements (ibid.). These types of partnerships were applied in Vallen, Pelarsalen and Torparängen districts, also with the intention to support research around such processes (ibid.). A different example is Skellefteå municipality, which is responsible of coordinating the Wood Innovation Cluster. The cluster was established in 2017 and brings together regional representatives and wood-building experts from the industry, research, and municipality. It aims to coordinate strategic efforts for the industry in the region and to conduct research, education, and experimental activities (Interviewee 7; Skellefteå.se 2023). One important development from this cooperation is the T2 College started in 2016 as a joint venture between the industry, municipalities, and upper secondary schools with the aim of developing and creating conditions for industrial education in the region.

Finally, working with marketing for creating an image about municipalities has also proved effective in transcending regulatory barriers. For instance, the

municipalities of Malmö and Växjö have supported wood construction via more subtle ways, such as using photos featuring wood construction and its benefits when presenting plans for a development site thus by influencing architects' proposals (Interviewee 6). Also, the focus on green cities has created a hype among planners, architects, and engineers in Sweden to seek good examples (Andersson 2020). Municipalities like Skellefteå and Växjö have from early on initiated somewhat standardised study tours using the umbrella concept 'wood house safaris' (Andersson 2020). The safaris are a form of policy mobilities practices to generate learning across a broad range of participants such as real estate developers, engineers, building contractors, architects, planners, politicians, and researchers (Ibid). Another subtle way of nudging contractors to choose wood in use in Skellefteå is requesting for a justification for why they have picked materials different than wood. Then the municipality invited contractors for a workshop together with researchers to identify possible problems of building with wood and identify solutions (Interviewee 7).



Photo: Gabriel Giacometti

On the flip side of the coin, there are a number of critical issues with the ambiguous role of public institutions. Authorities and practitioners seem to struggle with conflicting legislation and policy goals, e.g. free competitions and material-neutrality versus carbon-neutrality goals and wood strategies. The principle of material neutrality seems to affect the willingness of some Finnish and Swedish municipalities to act on wood's favour, or any other alternative with lower carbon footprint. At the same time, some believe that a positive result of not picking 'winners' (e.g. wood), is that it is triggering innovation using different types of products and hybrid use of materials. Furthermore, the lack of technical specifications, i.e., wood, in bidding processes, which contradicts municipalities' policy goals of increasing wood construction, seems to generate confusion among developers about the expectations and criteria used for the selection of winning projects. For instance, an evaluation of the land allocation process used

by Växjö municipality in Torparängen area, designated for wood construction, showed that both developers and the municipality practitioners are critical to the possible subjectivity of this process (Lindblad 2020). Despite an evaluation process was introduced prior to the start of the process, developers struggled to interpret the expectations from the municipality (ibid.). There also seemed to be a mixed understanding of who is the client, as the municipality saw itself as the "seller of land", whereas the developers saw it as "a buyer of a building solution". Municipalities, therefore, often lack the knowledge for how to design the processes and set clear criteria for evaluating proposals in a structured and objective way. This is evidenced in the rather ad-hoc methods and basis for decisions that municipalities recure to when selecting winning bids.



Photo: Gabriel Giacometti

Systems perspective to innovation in wood construction

According to one expert: "in the construction industry we have product and process innovations but also systemic innovations" (Interviewee 11). Systemic innovations "include organisational and 'actor-role' innovations" which, according to the expert, explains the core of systems integration where separate systems and sub-systems become interconnected in new ways. Technologies transcend sectors and cross-fertilise towards new ends, and novel actors as well as new ties between actors and supply chains emerge. Meanwhile, also established players change their roles, adapting to new conditions and exploring new opportunities (ibid.).

Barriers to wood construction discussed in previous chapters point towards structural inertia, which cannot be disrupted without systemic changes to the overall construction, forestry and related sectors, from legislation and policy to market conditions, funding structures, governance and collaboration set-ups, and a profound behavioural and cultural change. For over a century, building systems based on concrete and steel have maintained an unchallenged dominion, where established actors and lobby groups have had very little competition in the market space (Interviewees 1, 11). Over time, material suppliers, construction companies, real estate firms and other players along the supply chain have welded a strong mutually dependent relation making it difficult even for powerful industries such as forestry to wedge between these links. The unchallenged status quo was reinforced by large investments, well established supply-chains, business models, funding mechanisms designed for a specific type of construction, a long tradition of established practices, and a vast accumulated knowledge. Therefore, the well-functioning status quo offers no specific incentive for the established actors to enter a new playing field, which entails risks, new knowledge, new investments, new business models, and a re-organisation of the construction process and partnerships. Introducing wood, represented a leap onto the unknown. On top of that, the infant wood construction industry, while

still taking baby steps, experimenting, and solving all types of challenges, be it technical, regulatory, financial, or cultural, appeared far too utopian, unrealistic or at best to serve a niche market. At the systemic level, the effects of structural inertia are visible in a very tangible form: for example, in the slowness and reluctance of actors such as banks and insurance companies to offer more flexible options taking different building processes into consideration. Although this is now changing, the emergence of multi-storey wood building has been possible first, by a handful pioneering companies and also municipalities that have by-passed the established actors and processes, building the first pilots and slowly creating competing business ecosystems. Investing in technological innovation and knowledge-building, facilitating cooperation across sectors, academia, policymakers, and public authorities is then enabling systemic change. In what follows, we discuss some of the issues that humper or facilitate systemic change.

Knowledge building

Coordinated efforts in knowledge building are important because the lack of information about wood as construction material is among major barriers hindering the development of the sector. As seen in Ch.4, there has been several efforts in the national level, including several research programs launched in both Sweden and Finland, since the beginning of the 1990s, and state funding has allowed examining in more detail some practical problems such as related to acoustics and fire safety, as well as testing different construction systems (Interviewee 1). However, most work done to develop engineered wood products, or to solve the technical problems, has been conducted either by the pioneering companies themselves, or with their own funding. In addition of technical research, impacting the dominant education system, where for example civil engineers, planners, architects, and constructors gain their expertise, remains an important but complicated task. Unless well informed, these actors still expect wood to behave similarly to steel, for example, which leads to negative experiences that then enforce negative stereotypes about wood as material (Interviewee 3). For example, the notoriously expensive publicly procured wooden music hall in Lahti served for long as an example warning others off wood construction (Mölsä 2021).

In addition to technical research, the wood industry as a collective has played an important role in generating awareness for example by creating open national standards. Going forward, constructors could continue making it easier for customers to make estimations for their plans by setting prices more clearly to reflect the real costs of building in wood (Interviewee 13). Resource banks featuring exemplary solutions or for examples templates for alternative cooperation agreements based on life cycle thinking could be one way to use knowledge building for directing public resources more efficiently (Paavola 2019; Interview with IA). Efforts to synchronise business practices has been far from simple because all Nordic countries (let alone EU members) continue to have their own construction standards and regulations (Interviewee 3).

Perceptions

Since wood is considered a novel material and the layer of knowledge is thin, anything going wrong with wooden buildings can become newsworthy, reinforcing possible negative stereotypes. Therefore, some experts favour safer projects such as multi-storey apartment blocks (compared to tall, experimental buildings) as the best strategic move to increase a market share (Interviewee 11). As an example of negative perceptions, Finland's key breakthrough in wood construction experiments resulted in mixed results. In 1995, the fire laboratory of the Technical Research Centre of Finland (VTT) succeeded in testing wooden frames against an hour of exposure to fire, which led to building a three-storey apartment building in Helsinki. However, the final costs of this pilot project rose high above initial estimates, leading to the sacking of the CEO of the construction company and general mistrust towards wood as material (Rakennuslehti 2016). Behavioural factors influencing the stakeholder ecosystem have considerable influence and they come in many shapes and forms. In addition to common fears associating wood to fire hazards, mould and moisture, public opposition may also rise in the future because of fear of deforestation or unsustainable forest management. This is especially true beyond the Nordic countries, where deforestation of primary forests remains common (Interviewee 11), but also in Nordic countries where the standard forest management practices are increasingly alleged to be unsustainable. Combating negative associations towards wood construction, the industry, and advocates appeal to a wide spectrum of factors, including broader societal values, perceptions, and attitudes towards the material (either real or imaginary), planning systems and public procurement, general rules and legislation, certification schemes, supply of options (material-wise) from timber industry and their search for new markets, and the interest of architects. 'Wood house safaris' is one initiative emerging from Värmland and Skellefteå municipalities as a way to challenge the inertia posed by negative perceptions and fears. Beyond simply building awareness, these safaris are an effective way of selling the idea of 'success' which can spin-off into a self-reinforcing cycle, where new projects and investments are attracted towards examples of previous success stories – or at least narratives of success.

Networks

Not only structural inertia, but also successes in gaining a foothold for wood in the construction market over decades links closely with building and relying on both formal and informal networks and actors. Failures often coincide with a lack of support systems. One of most concentrated efforts to build networks and collaboration in Sweden is the platform established by Trästad Sverige, discussed in Ch. 4. During periods when there has been no state funding, active members have been able to keep the momentum going. Linking to the weight a place has, here we again witness the role of active regional players. Regional and local representatives were closely involved in Trästad Sverige from the beginning of the association, including the governor of the county administrative board of Västerbotten chairing the board.

Place-based developments

The national level is often too big of a scale for driving industrial transformations. Local, place-based initiatives often prove more effective in mobilising local businesses and other actors and creating common grounds. Geography generally determines regions' industrial legacy, the resources available, the knowledge and skills, the established networks, as well as the 'tacit knowledge' or more implicit societal norms or 'ways-to-do-things'. The local level is a more 'human scale' where people know each other and have built trust relations. Skellefteå and the broader Västerbotten region is a clear example of this, where many have referred that the short distance (metaphorically) between and even social relations between people in the industry, local authority, and university has been crucial in bringing them together towards common goals and quickly take solid steps. For instance, the municipality commissioned the first wooden multi-storey building as early as 1995, the same year the new building codes entered into force. Simultaneously, Martinsons, the local wood industry revived the production of Mass Timber products, began piloting, and making long-term investments. Moreover, place-based developments are often resulting from the capacity of individuals of mobilising change. In Skellefteå a visionary and bold politician was a significant figure in pushing forward change. Skellefteå's ability to tap into its specific strengths, resources and historical roots has been a decisive factor in its successes in promoting wood construction. The municipality is in an advantageous position as the owner of Skellefteå kraft, a large energy company, Skebo, the municipal housing company and is co-owner of Kommuninvest, a bank that offers 'green loans' with low interest rates. Much of the land is also municipally owned, as it is common in Sweden. Skellefteå municipality is, therefore, able to lead by example and build many of the city's wood buildings, including public schools, event halls and parking lots, as well as apartment buildings. Combined with strong industrial legacy in forestry, these reasons have enabled the city to take a less interventional and more organic approach in wood construction policies, possibly lessening the risk of tensions (Interviewee 7).

However, development can also be driven far from the industry where urban areas have taken the lead, highlighting the role that zoning and local sustainability goals may take in supporting wood construction (Interviewee 12; WoodJoensuu 2022). Place is relevant when assessing the environmental footprint of construction as proximity to the material plays determines the emissions from transport. To reviewing the sustainability of material itself, it is essential to assess e.g. what material is locally available and what is durable under the local conditions. For example, the sustainability of wood construction in Iceland, where most construction materials are imported, should be evaluated differently than in forest regions of Sweden and Finland (Palmadottir at panel debate at the Icelandic Democracy Festival, Fundur fólksins, 2022).

On the other hand, the global perspective and networks at national and international level also play a key role as it allows actors to transcend the limits of geography. For example, since joining the EU, Region Västerbotten has found it easier to gain allies in Brussels than in Stockholm. As a local public servant

explained, actors and networks in the region have benefitted from collaborating and connecting value chains internationally (Interviewee 10).

Funding structures

As a nascent industry or sub-sector, wood construction is (or was in the case of Sweden) in a position as outlier in the market, affecting the possibilities of accessing the necessary funding. In addition, the lack of built experience, at least in early phases, was deemed risky for insurance companies and thus demanded higher fees for wood-based projects. The common financial structure used by banks can also be problematic for wood construction projects because its work phases are organised differently. Often, banks make payments to constructors in different phases of the building process e.g. foundations, framing, interior and exterior, as each completed phase can be used as a warranty of value. Compared to this arrangement, wooden building, especially modular building systems carry most of the work offsite in a factory and then assembled onsite at once. Standard loan structures especially restraints the possibilities of small and medium-sized companies that do not necessarily have the cash flow to invest in the whole building process. In Sweden, municipalities have been able to circumvent the problem of funding by seeking 'green loans' from their jointly owned investment bank called Svenska Kommuninvest. Being owned by a collective of municipalities, the bank supports their interests. In this case, municipally led projects that classify as 'Environmental Buildings' in accordance with 'Miljöbyggnad' certification scheme, can receive lower interest rates (Interviewee 7). In general, however, banks have been slow to adapt. And although companies have found ways around, the increasing number of wood buildings calls for a more systematic change in banks' funding structures for the construction sector (Interviewee 2).

Cost-effectiveness

Insufficient networks and experience in early days made wood construction less cost-effective than traditional construction. This inevitable situation for many emerging industries represent a major customers and contractors will still favour cost-effectiveness over sustainability (Interviewee 11). The differences in market conditions between Sweden and Finland can be partially traced to the lack of a systemic effort to invest in research, development, and innovation in Finland. For example, in the 1960s Sweden accepted a proposition of setting money aside from salaries to research and has used these funds to establish Byggnadsnäringsrådet, which today finances research with hundreds of millions of SEK annually. In Finland, a similar initiative was rejected (Rakennuslehti 2016). Finnish constructors have struggled to build efficient construction processes, and therefore battle with higher costs to a much larger extent than their peers in Sweden. Considering that the timeline of prefabricated buildings is more predictable, successful knowledge building should lessen the burden of perceived risks in wood construction with time. An important factor would be to get more current data for risk analyses, on which financing and insurance decisions are based on (Interviewee 6).

Systems changing

One expert compared operating in a construction market to training an army (Interviewee 2). Both processes are usually carried out in a highly similar way, so that any new components must be carefully assessed and aligned with the existing parts of the system. Since most new endeavours imply taking a risk of not meeting the pre-fixed price calculated with the customers, companies tend to avoid new solutions even if they would be more efficient in the long run. However, things are shifting. Construction companies are presently getting involved in wood construction because they realise that the market demand for it is growing. New involvement entails building more domestic factories for mass timber products and modular units, but also new players and start-ups filling market gaps with innovative products and solutions, leading to rapid increase in volumes. As the market grows, all processes involved are becoming more cost-effective as well. As the same expert puts it, "you just need to shake the ketchup bottle for some time and then it all comes out at once" (Interviewee 2). But who is responsible for shaking the bottle? In this case, municipalities have played a key role in coordinating action and establishing ties between key players. The municipal governance and planning systems can be both a barrier and a useful tool to make things happen. Planning systems and zoning regulations have generally been based on conventional construction systems, which represent a problem for certain wood construction alternatives. Adapting planning systems has been necessary to enable wood construction to compete under the same rules of the game than conventional construction. Indeed, in successful cases, municipalities have used public procurement and planning systems strategically to favour wood construction and circumvent systemic barriers.



Photo: Gabriel Giacometti

Conclusions: the roles of actors

This case shows that the development of the wood construction sector is complex, and causality cannot be attributed to single actors or decisions, but to the sum of different efforts. It is precisely at the intersection between key players where change originates, with collaboration as the catalyser and trust as the glue that binds them together. The fact that there is no "golden ticket", a singular innovation, event, or driver that explains the birth of multi-storey wood construction, implies that the nature of innovation differs from other types of ground-breaking innovations. For instance, the smart phone had an immediate global effect, rapidly replacing and rendering obsolete previous technologies and products, profoundly transforming the industry, the way we communicate, and society at large. However, we do not see a rush towards adopting timber as an alternative in construction or the obsolescence of established building systems, and we should not expect a societal impact of the same magnitude. In a slower pace, however, wood construction does seem to have the potential to profoundly transform the construction industry in suitable parts of the world, including the Nordic Countries (Interviewee 11). This most probably will not mean the complete replacement of existing building systems and actors, but will disrupt the current business ecosystems, the business models and add diversity to the existing market options. In short, this is a case of systems innovation rather than a product or technological innovation alone.

In this study, we have identified a number of key moments or events in history that have triggered major development in the form of technological innovation or in building industrial capacity and knowledge. From the contracts issued by the Swedish military in the 1940s, the Million Home programme in the 1960s-70s, the rapid urbanisation processes post-war (and reconstruction in the case of Finland), to more recent changes in legislation, first enabling multi-storey building in wood, and then the recent climate declarations and limit-values on emissions. The state, both in Sweden and Finland, has enabled technological development by funding and supporting R&D programmes and setting strategies for development. All these events, old and new, highlight the strong influence of

state policy and legislation in boosting the market for wood construction. On the other hand, it was the state to halt development to begin with via prohibition on MSWC imposed in the late 1800's.

Accession to the EU and processes of harmonisation of legislation have also triggered important changes on the rules of the game, even unintentionally. The EU, however, has also a big role to play when it comes to setting environmental goals, as well as with more soft approaches, such as issuing the voluntary recommendations for green procurement in the construction of offices.

However, once the rules of the game have changed, the role of the national and supra-national level becomes less prominent, whereas sub-national authorities play a more practical role in supporting development in several ways. Selected municipalities reacted quickly to the legislative changes, building on local industrial and economic competitive advantages. Their closer proximity to business networks and other community actors allowed them, often through more informal means, to build momentum and create a common vision onto how to seize the new opportunities. Establishing trust relations with businesses was key for them to take risks and invest in new infrastructure and work towards entering the new market niche. In taking part of knowledge creation projects (e.g. Trästad 2012), and commissioning the first pilot buildings, municipalities have also taken a more entrepreneurial role. Through 'green finance', municipalities have stimulated market creation and supported companies to build capacities and experience.

The private sector plays a more direct role in industrial development, starting from exploring and investing in product development, designing new building systems, piloting, to finally producing materials, building elements and erecting buildings. However, the private sector is heterogenous and includes many actors along supply chains. Only a handful of them are risk-taking pioneers, whereas the grand majority, at least in the early development stages, belong to the establishment and either resist change or are comfortable with the status quo, including contractors, real estate companies, banks, and insurance companies. However, from the pioneering companies, some have come from the outside of the established business ecosystem (wood industry), but others have also taken a step up from the inside (construction sector). In both cases, they needed to circumvent the existing actors, supply chains, business and finance models to be able to open up a place in the market.

R&D has been an essential mechanism for progress, whether it comes from academia itself, the industry, or in partnership. The public sector and academia have recognised the importance of funding large scale R&D programmes for knowledge development, and the importance of setting triple helix partnerships, not only to solve technical challenges but also systemic ones. Academia and education programmes have also been successful in generating awareness.

Banks and insurance companies have instead played a deterrent role, being slow in adapting and not offering options to a nascent industry, which as an outlier in the market requires risk capital and support. Lastly, the society at large and

changing values have added pressure to policymaking and the industry in delivering on the sustainability goals and the green agenda. Changing values also influence perceptions towards modern wood buildings as they become a symbol of status and urban renewal.

Changing roles of actors

When looking at the role different actors play, it is important to recognise their evolution over time. For example, authorities have taken a step up from their normal administrative tasks to become drivers of development or entrepreneurial. Municipalities have learnt to navigate around the legislation to favour wood construction despite of the principle of material neutrality. When entering new market segments or engaging in new parts of the supply chains, private companies are also evolving and mutating. For instance, to get around the resistance of the well-established actors or reluctance from financiers to support their ventures, pioneer companies have transformed from being a e.g. wood industry to become a construction company or vice versa, or simply start side companies to deliver supplementary services e.g. design and consulting. In this process, knowledge flows between industries, by professionals moving across industries, have been necessary to build new capacities. As a result of these changes, the business ecosystems have transformed.

In short, the systemic nature of industrial transformation means that no single interest group, no matter how strong, nor a single factor can be attributed the whole responsibility for driving change. Systems barriers are embedded within the interlinkages between actors, nodes in the supply chains and the overall industry organisation. Structural inertia stems from long established traditions and practices, network gaps, insufficient knowledge, experience and skills, and the risks involved in developing a new industry. In this situation, even major legislation and policy shifts do not automatically lead to an upsurge in demand, as wood companies noticed when their initial optimism following the regulative reforms in 1994 and onwards was perhaps premature. Instead of waiting for transition to occur by itself, actors needed to nurse the nascent industry, establish new partnerships and find creative ways to open market niches. One way to achieve this, for example, is by first supporting 'champions' to create a customer base with the help of successful pilot projects, which then will help create more demand. All in all, it is precisely at the intersection between key players where change emerges, with collaboration boosting systems innovation.

References

Bionova Ltd. (2017). Tiekartta rakennuksen elinkaaren hiilijalanjäljen huomioimiseksi rakentamisen ohjauksessa.

Boverket. Climate declaration for new buildings. Website: Boverket.se. Access 31-10-2022

Byggvärlden, 2022. Skellefteå bygger bro i trä. Available at: <https://www.byggvarlden.se/skelleftea-bygger-bro-i-tra/>

Ekholm, T., 2011. Trästad 2012 utvecklar byggbranschen. Byggnyheter.se 4th June 2011. Available at: <https://www.byggnyheter.se/20190804/5720/trastad-2012-utvecklar-byggbranschen>

Elspecta AB. 89/106/EEC. Website. Available at: <https://elspecta-ab.com/en/?layout=edit&id=7>

The European Commission, 2016. Green Public Procurement. Available at: https://ec.europa.eu/environment/gpp/news_archive_en.htm

Finnish Government (Valtioneuvosto), 4th June 2021. Rakennuksen ilmastoselvityksen asetustunnus lausunnoille – tavoitteena yhdenmukainen ja luotettava vähähiilisuuden arviointi. Available at: <https://valtioneuvosto.fi/-/1410903/rakennusten-ilmastoselvityksen-asetustunnus-lausunnoille-tavoitteena-yhdenmukainen-ja-luotettava-vahahiilisuuden-arviointi>

Kunskapsförmedlingen, 2022. Lean Wood Engineering. Website. Available at: [Lean Wood Engineering—Kunskapsförmedlingen \(kunskapsformedlingen.se\)](https://kunskapsformedlingen.se/lean-wood-engineering)

Laapotti, S., 2020. Rakennetaanko puusta vai rahasta – puu taipuisi moneen, mutta rahayhtälö sakkaa. University of Tampere 07.12.2020. Available at: <https://www.tuni.fi/unit-magazine/artikkelit/rakennetaanko-puusta-vai-rahasta-puu-taipuisi-moneen-mutta-rahayhtalo-sakkaa>

Lindblad, F. (2020) Växjö Municipality's Planning Strategy to Increase the Construction of Wooden Multi-Family Buildings. Sustainability 2020, 12, 4915. DOI: 10.3390/su12124915

LTU, 25.8 2011. Nordens längsta snedstagsbro i trä invigd. Available at: <https://www.ltu.se/research/subjects/Trateknik/2.39050/Nordens-langsta-snedstagsbro-i-tra-invigd-1.82355>

Martinsons (2015) Martinsons invests SEK 80 million in Cross Laminated Timber production line. Cision News. Web-article: <https://news.cision.com/martinsons/r/martinsons-invests-sek-80-million-in-cross-laminated-timber-production-line,c9864685>

Manninen, H. (2014). Long-term outlook for engineered wood products in Europe. European Forest Institute.

Metsä Groupin Viesti 4/2013. Published on Nov 28, 2013. Available at:

https://issuu.com/metsagroup/docs/mg_viesti_4_2013/52

Mölsä, S., 30.8. 2016. 50 vuotta kehitystyötä: VTT ja Tekes ovat monen rakennusalan menestystarinan takana. Rakennuslehti. Available at:

<https://www.rakennuslehti.fi/2016/05/vtt-ja-tekes-ovat-monen-rakennusalan-menestystarinan-takana/>

Mölsä, S., 2021. Analyysi: Puurakentaminen on liian kallista, siksi sen edistämisessä siirryttiin pakeroon. Rakennuslehti 25th March 2021. Available at:

<https://www.rakennuslehti.fi/2021/03/analyysi-puurakentamista-on-edistetty-yli-25-vuotta-mutta-vasta-pakko-tuotti-tulosta/>

Nord, T. (2008). Prefabrication Strategies in the Timber Housing Industry: Case studies from Swedish and Austrian markets. Luleå University of Technology. Technical Report: 2008:16 - ISSN: 1402-1536

Näringsdepartementet (2004). Mer trä in byggandet: Underlag för en nationell strategi att främja användning av trä i byggandet. [More Wood in Construction strategy]. Ds 2004:1

NTT Woodnet (2012). Vad händer efter Trästad 2012? Access: 27, October 2022. Website:

<https://www.woodnet.se/article/view/429632/vad-hander-efter-trastad-2012>

OneClick, October 2022. Construction carbon regulations in Europe. Review & best practises.

Paavola, H., 2019. Puurakentamisen ohjelman kehittävä arviointi. Witmill and Ministry of Environment. Available at:

<https://valtioneuvosto.fi/-/1410903/puurakentamisen-ohjelman-valiarviointi-puurakentamisella-jo-vahva-tuki-mutta-kunnianhimon-tasoa-varaa-nostaa>

Palmadottir A., Arkitekt FAÍ sap arkitektar. 2022. Panelist at: The climate villain goes green – the role and responsibility of the construction industry to reduce its emissions. Icelandic Democracy Festival, Fundur fólksins, 2022 Sustainable Construction project.

Purdy, Sirpa 2010. Suomalainen moderni puuasuntorakentaminen 1990- ja 2000-lukujen vaihteessa. Tapausesimerkkinä Niiralan Kulma Oy:n modernit puuvuokratalot Kuopiossa. Master thesis. University of Jyväskylä.

Puu-lehti, 2017. Opas julkisiin hankintoihin. Available at:

https://puutuoteteollisuus.fi/images/pdf/Julkkis_sivuittain_LOW.pdf

Railio, J., 2014. Construction Products Regulation (CPR) applies also to HVAC products. Rehva Journal March 2014. Available at: [10-11 CPR RJ1402 WEB.pdf \(rehva.eu\)](https://www.rehva.eu/10-11-CPR-RJ1402-WEB.pdf)

Ramage, M.H.; BurrIDGE, H.; Busse-Wicher, M.; Fereday, G.; Reynolds, T.; Shah, D.; Wu, G.; Yu, L.; Fleming, P.; Densley-Tingley, D.; et al. (2017) The wood from the

trees: The use of timber in construction. *Renew. Sustain. Energy Rev.* 68, 333–359.

Rasmussen, F.N.; Andersen, C.E.; Wittchen, A.; Hansen, R.N.; Birgisdóttir, H. (2021) Environmental Product Declarations of Structural Wood: A Review of Impacts and Potential Pitfalls for Practice. *Buildings*, 11, 362.

<https://doi.org/10.3390/buildings11080362>

Saarnivaara, V-P., 1998. User-oriented industrialized construction as a strategic target in Finland.

SBK-säätiö, 2009. Tehdään elementeistä: Suomalaisen betonielementtirakentamisen historia

Siikanen, Unto 2008. Puurakentaminen. Helsinki: Rakennustieto.

Skellefteå.se, 2023. Wood Innovation Cluster. Available at:

skelleftea.se/trainnovationsklustret

Skogsindustrierna, 19.11. 2008. Lorentz Andersson dubbad till träriddare.

Available at: <https://news.cision.com/se/skogsindustrierna/r/lorentz-andersson-dubbad-till-trariddare,c394357>

Smart City Sweden, 2020. Wooden construction – The future in Urban Planning.

Available at: <https://smartcitysweden.com/wooden-construction-the-future-in-urban-planning/>

Stehn, L., 2022. Lean Wood Engineering. Available at:

https://www.ltu.se/cms_fs/1.51998!/lars%20stehn_lwe.pdf

Suikkari, R., 2007. Paloturvallisuus ja kaupunkipalot Suomen puukaupungeissa – historiasta nykypäivään. Licentiate Thesis. University of Oulu.

Suomen liimapuuyhdistys ry and Puuinfo Oy, 2014. Liimapuukäsikirja Osa 1. Libris Oy.

Swedish Forest Agency (2020) Market Statement 2020 – SWEDEN. UNECE Timber Committee Market Discussion 4-6 November 2020 Geneva, Switzerland

Swedish Wood. Wood in the construction process. Website:

<https://www.swedishwood.com/building-with-wood/construction/building-with-wood/> Access: 02/10/2022.

The Ministry of Environment (Ympäristöministeriö), 2022a. Vähähiilinen rakentaminen ("Low carbon construction"). Available at:

<https://ym.fi/vahahiilinen-rakentaminen>

The Ministry of Environment (Ympäristöministeriö), 2022b. Puun käyttö julkisessa rakentamisessa: Hankintaopas. Ympäristöministeriön julkaisuja 2022:25.

Available at:

https://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/164407/YM_2022_25.pdf?sequence=4

Tina Wik Arkitekter, 2022. Wälludden I. Website. Available at:

<https://tinawikarkitekter.se/wordpress/walludden-i/>

Tolppanen, J., Karjalainen, M., Lahtela, T., Viljakainen, M., 2013. Suomalainen puukerrostalo – Rakenteet, suunnittelu ja rakentaminen. Opetushallitus.

Träbyggnadskansliet 2014

<https://trabyggnadskansliet.se/kunskap/2021/pressmeddelande-industriellt-byggande/>

Växjö Municipality (2013). Växjö the modern wooden city: Växjö Municipality's Wood Construction Strategy.

Wood Joensuu, 2022. Puurakentaminen. Website. Available at:

<https://woodjoensuu.fi/teemat/puurakentaminen/>

Woodnet, 2014. Sveriges första guldklassade skola helt i trä. Available at:

https://www.woodnet.se/article/view/430348/sveriges_forsta_guldklassade_skola_helt_i_tra

Interview list

Sweden

- Interview 1: RISE
- Interview 2: Independent Consultant – industry expert
- Interview 3: Swedish Wood (Svenskt Trä)
- Interview 4: White Arkitekter
- Interview 5: Swedish National Board of Housing, Building and Planning (Boverket)
- Interview 6: Trästad Sverige (Wood City Sweden)
- Interview 7: Skellefteå Municipality
- Interview 8: Västerbotten County Administrative Board
- Interview 9: Martinsons (Holm)
- Interview 10: Region Västerbotten

Finland

- Interview 11: Aalto University
- Interview 12: University of Helsinki
- Interview 13: Independent, former director of Business Finland

Nordic

- Interview 14: Nordic Council of Ministers

About this publication

Innovation Dynamics in Multi-storey-Wood Construction in Sweden and Finland

Authors: Alberto Giacometti & Hilma Salonen

This working paper is a part of the project "[Systems perspectives on Green Innovation \(GRINGO\)](#)". The project aims to uncover existing bottlenecks for sectors/businesses engaged in green transitions. [The study is conducted under the Nordic Thematic Group for Green, Innovative and Resilient Regions \(2021-2024\).](#)

Cover photo: Gabriel Giacometti & Alberto Giacometti

Layout: Kotryna Juskaite, Nordregio

Nordregio working paper 2023:2

ISBN: 978-91-8001-040-5 (online)

ISBN: 978-91-8001-041-2 (pdf)

ISSN: 1403-2511

DOI: <http://doi.org/10.6027/WP2023:2.1403-2511>

© Nordregio 2023

www.nordregio.org