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CHALLENGES IN THE TRANSITION TO CIRCULARITY IN MULTI-STOREY WOOD BUILDING CONSTRUCTION – SCANDINAVIAN INDUSTRY PERSPECTIVE

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ABSTRACT: Transitioning towards a more circular economy is crucial to tackle the urgent challenges of climate change, depletion of primary raw materials, and waste in our society. Focusing particularly on multi-storey wood building construction in Scandinavia, this study aims to identify the primary challenges for maximizing circularity potential. Through a series of workshops and in-depth interviews with stakeholders across the construction industry value chain, this research seeks to uncover insights into enhancing circular practices.

The study shows that time and cost constraints pose the main limitations to the reuse of materials and use of techniques to further improve material reuse in the future. Reusing materials is often at least as costly as using new virgin materials. However, by breaking down the constraints of "time and money" into more specific aspects opportunities for cost-effectiveness and efficiency emerge. According to the stakeholders in this study, the two most important aspects to focus on to make circular timber constructions more feasible and cost and time effective are “Logistics chain for reused materials” and “CE-labelling and warranties of reused materials”.

KEYWORDS: Circularity, Reuse, Timber, Multi-Storey Building, Cross-Laminated Timber (CLT).

1 – INTRODUCTION

For years, discussions in the Scandinavian construction industry primarily focused on improving energy efficiency to minimize emissions, particularly those from heating. However, when researchers conducted life cycle assessment (LCA), they found that the construction process itself accounts for more than half of the climate impact of buildings over a 50-year period [1]. For instance, an LCA of a Swedish building by Petrovic et al. [2] found that material-related impacts from the building's production and maintenance stages account for 67% of the total life cycle carbon footprint, while operational energy accounts for 21%. One reason for this trend is that the Scandinavia, including in Sweden, has less emissions from building operation due to a low carbon electricity mix compared to many other European countries, and has also made significant progress regarding energy efficiency of buildings.

Nevertheless, significant emissions still occur during the production phase of buildings. Instead of constructing new buildings using high-emission virgin materials, Scandinavian countries should take the lead in the next step of decarbonizing the building sector by accelerating the preservation and reuse of existing buildings and building materials.

The Circularity Gap Report measures the global circularity rate, which indicates how much of the materials we use are cycled back into the economy after use. The latest report states that the concept of circular economy is gaining popularity, but there is a notable lack of concrete actions to support it. In Sweden, this can be felt. While awareness and motivation are increasing, actual implementation lags, with businesses and government initiatives often failing to translate interest into practical, impactful measures. In 2024, only 3,4% of construction material is cycled back into the economy after use [3].

Circular Economy (CE) can be implemented through principles and strategies such as the reduction of virgin material use by design, along with value-retention processes such as reusing, repairing, repurposing and recycling [4]. The obvious reason why these principles and strategies are not more common is the fact they are more expensive and time-consuming than linear practices using virgin material. The costs associated with the

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deconstruction, reconditioning, transportation, storing, certifying and creating marketplaces along with the time required for circular practices, create significant barriers to adoption in the construction industry [5, 6].

Multi-storey wood buildings are increasing in Scandinavia, and wood is often cited as a sustainable building material due to its renewable nature and lower carbon footprint compared to other materials like concrete and steel. However, despite these advantages, the circularity of wood in multi-storey construction remains limited. Examples of reusing or recycling timber at a large scale are rare, and the potential for circularity in timber construction remains underexplored. As much as 90% of recovered post-use wood in Sweden is directly used for energy, mainly for generation of district heating [7].

But there are several noteworthy initiatives for circular wood construction (see Figure 1). A prominent example is “SirkTre” in Norway [8]. This project transforms waste wood into reclaimed timber and cross-laminated timber (CLT) while developing new standards for reclaimed timber in construction to improve quality assurance and potentially reduce costs. The project showcases multiple demonstrations of how reclaimed wood can be repurposed into CLT elements or reconditioned timber, emphasizing the potential for sustainable material reuse in the construction sector.

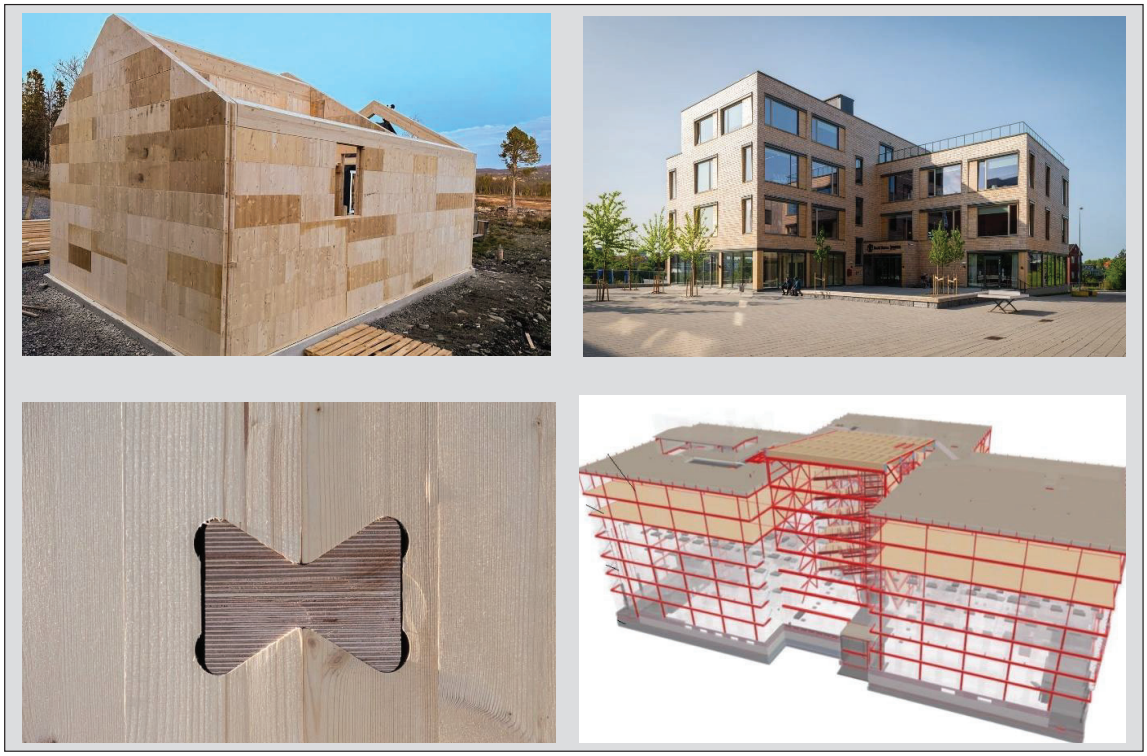

Figure 1. Cross-laminated timber (CLT) elements made of reclaimed wood in “SirkTre”, Upper right: “Hasletre”, a building designed for deconstruction, reuse and adaptability, Lower left: Mounting system in wood, Lower right: LUMI in Uppsala, a building with timber floors on top of a preserved concrete structure.

There are also examples of new building design that prioritize future reuse or an extended building lifespan (Downstream). Buildings can be specifically designed for deconstruction, reuse, and adaptability to minimize these extensive emissions. Most of these examples remain academic or conceptual projects, such as "Future Design" by the Swedish Research Institute RISE [9]. However, a realized example is "Hasletre" in Norway, developed by the architectural firm Oslotre and Höegh Properties. This project features flexible mounting systems without steel, enabling the complete disassembly and reassembly of the structure [10]. Other of examples multi-storey timber buildings with innovative solutions for future flexibility are “Magasin-X” in Uppsala, Sweden by White architects and Vasakronan and “Kajstaden” by CF Möller architects and Trenum Västerås AB [11, 12].

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Timber can also indirectly facilitate CE. "Timber on Top," demonstrates how CLT can support the reuse of existing concrete structures by enabling additional stories to be built on top. This combination of concrete and CLT extends building lifespans and optimizes resource use [12]. A large-scale example of this total renovation approach is the LUMI building, also in Uppsala and designed by White Architects and developed by Vasakronan. Here, about 100 $kgCO_2e/m^2$ (gross floor area) emissions were saved compared to building a new pre-cast concrete building [13]. In Scandinavia and the rest of the EU, there is little need for entirely new buildings. The LUMI project represents a more efficient and environmentally friendly approach to achieving the decarbonization of the building sector. By 2050, the current renovation rate—currently around 1 to 1.5 percent of all buildings annually in Europe—needs to be doubled or even tripled [14].

2 –BACKGROUND AND OBJECTIVE

This study is part of a research project aimed at identifying opportunities and developing tools to enhance circularity in multi-storey wood building construction funded by the Kamprad Foundation [15]. The project is to quantify potential environmental savings through LCA. Additionally, the project investigates the challenges encountered by construction companies within the supply chain as they transition toward circular solutions. This paper focuses on the latter aspect of the project, and its objectives are as follows:

- identify key areas of interest and priority where the industry needs support in circular CLT construction.
- identify and categorize the main challenges in the transition toward circular solutions within the wood construction industry.
- investigate the individual and collective challenges faced by the various actors within the wood multi-storey building construction value chain.

3 – METHODOLOGY

The methodology includes a literature study, stakeholder workshops, and interviews, focusing on identifying key areas of interest, requirements, and barriers for circular construction in multi-storey wood buildings, with an emphasis on CLT buildings. This enabled an appreciation of industry's viewpoints and potential pathways forward.

3.1 LITERATURE STUDY

Literature studies were conducted to establish knowledge base on CE in multi-storey wood building constructions, to facilitate the workshop and interviews.

3.2 WORKSHOPS

Two stakeholder workshops were conducted to facilitate collective discussions on circularity in multi-storey building construction. These workshops aimed to foster knowledge exchange with industry professionals. The details of the workshops and their focus are outlined as follows:

- Workshop 1, held on April 17, 2024: Focused on identifying key areas of interest and priority where actors outside the value chain can support the industry in circular CLT construction. Stakeholders were asked to highlight the most effective ways in which academia can support the industry and relevant authorities in the transition.
- Workshop 2, held on October 4, 2024: Explored specific challenges to increasing circularity in multi-storey wood building constructions, with discussions on regulatory, technical, and design-related barriers. The participants first voted on the identified challenge categories. This was followed by group discussions to further explore and elaborate on the central question:

  ''**What are the challenges for CE applications in wood construction?**''

The workshops incorporated expert presentations, structured group discussions, and interactive surveys to capture participant input.

3.3 INTERVIEWS

To gain insights into the barriers and opportunities for circular multi-storey wood building construction, semi-structured interviews were conducted with key stakeholders in Sweden and Norway. The semi-structured format allowed for flexibility in exploring specific topics while ensuring consistency across interviews.

The interview process was designed to capture diverse perspectives across the construction value chain. Participants were selected based on their expertise and involvement in CLT building projects. The stakeholders interviewed encompassed CLT manufacturers, architects, structural engineers, contractors, consultants, project owners, researchers, and clients.

A predefined set of questions guided the discussions, focusing on technical, regulatory, and market-related challenges in circular multi-storey wood building constructions. Participants were also encouraged to elaborate on emerging themes beyond the core questions. A thematic analysis approach was applied to identify key patterns, recurring themes, and stakeholder concerns in

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the interviews. This ensured that the findings reflected both common challenges and unique insights from different industry participants and roles.

4 – RESULTS

4.1 PRIORITY AREAS TO SUPPORT THE INDUSTRY IN CE DEVELOPMENT IN CLT BUILDINGS

Workshop 1 focused on identifying the most important support needs of the industry value chain in circular CLT construction. The priority was to establish a foundation on how academia can support the industry and policymakers. Figure 2 summarizes the results of e-votes, highlighting the needs and priorities among stakeholders who participated in the project workshops. The stakeholders prioritized the assessment of environmental benefits of CE strategies and addressing technical challenges, emphasizing the need for reliable impact measurements and practical solutions. CE-labelling and principles for circular multi-storey wood building construction emerged as an important consideration, reflecting the demand for clear frameworks and guidelines. There was also interest in showcasing successful examples and flagship projects, and fostering industry-wide dialogue to support knowledge-sharing on strategies for circularity in multi-storey wood building construction. Interest in digital solutions, marketplaces, and procurement strategies were also noted.

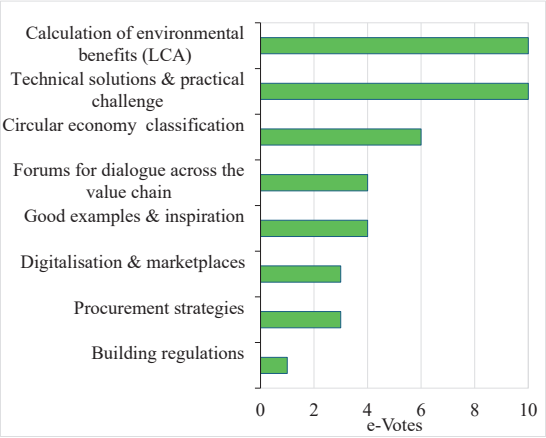

Figure 2: Interest and priority areas to support industry in circular multi-storey wood building construction, focusing on CLT buildings.

4.2 CE CHALLENGES IN WOOD MULTI-STOREY CONSTRUCTION

Workshop 2 followed up by narrowing down the discussions on regulatory, technical, and design-related barriers. Table 1 summarizes key challenges identified by stakeholders regarding application of CE principles in wood building, based on discussions in the project workshops.

Each challenge was ranked according to the number of votes from the stakeholders. The most prevalent issue highlighted was the lack of an established logistics chain, leading to limited supply of reusable materials. Secondly, the stakeholders highlighted the absence of CE-labelling and warranties for reused materials as a major challenge to circularity. Additional challenges include procurement challenges, technical difficulties and building regulations which are not adapted to support for material reuse in new building applications.

Table 1: Challenges in the transitioning towards a more CE in Multi-Storey Wood Building Construction ranked by number of e-votes by actors in the value chain.

Challenge	Votes (Actors)
Logistics chain and storage issues • Lack of an established logistics chain and storage space limits the supply of reusable materials.	28 (Clients, Producers, Architects, Construction companies, Warehouses for construction material)
CE-labelling and warranties • Reused materials lack CE-labeling and warranties, creating trust issues for reuse.	24 (Producers, Structural design companies, Construction companies, Warehouses for construction material)
Procurement challenges • Lack of experience with tendering processes for reused materials, leading to fear of failure. • Inflexibility in design and planning (e.g., building permits).	19 (Architects, Structural design companies, Clients, Construction companies)
Technical challenges • Difficulty in matching reused materials with new ones. • Lack of mounting systems	15 (Producers, Architects, Construction companies)
Building regulations • Existing regulations are not adapted to support the reuse of building materials.	12 (Producers, Structural design companies, Construction companies)

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4.3 INSIGHTS FROM INTERVIEWS

In the interviews, some previously identified challenges were confirmed, and additional dimensions emerged during this phase of data collection. The key findings and insights are summarized in the themes below.

Logistical challenges are central

The stakeholders agree that the main challenge to circularity in wood construction lies in logistics. Proper systems need to be developed to facilitate the transportation, storage, reconditioning and reallocation of materials, which will help enable large-scale reuse and lower costs. This is essential for the whole value chain.

EU Taxonomy and policy gaps

The lack of incentives in the current EU taxonomy framework does not encourage the use of circular solutions in construction. Buildings today are only designed for a lifetime of 50 years and a linear economy. The absence of policy-driven incentives could hinder the broader adoption of circular approaches for wood multi-storey buildings, even though the material itself has potential for reuse. Incentives and regulations should be aimed at clients.

Reusing CLT elements is feasible but can be made simpler

CLT elements can be reused, but disassembly can be challenging as unscrewing is sometimes difficult, and cutting them loose may be the only way to enable reuse. However, it is possible to design and mount CLT elements for greater flexibility and circular solutions. The CLT producers, structural design companies and architects agreed on this. However, for producers to make the necessary changes to make CLT elements more modular and flexible, a demand for such solutions must be created.

Environmental friendliness of wood buildings lowers industry incentives

Since wood is already perceived as an environmentally friendly material, the construction industry might not prioritize additional efforts toward circularity. This perception may result in less focus on finding circular solutions, as wood is already considered a sustainable option compared to other materials. The carbon footprint over the complete life cycle of the building is assessed and optimised from a life cycle perspective following the normative standard EN 15978 [16].

5 – DISCUSSION

The next step in decarbonizing the building sector, after focusing on operational energy, should be to accelerate the preservation and reuse of existing buildings and building materials. Scandinavia has reached a point where it can take the lead in this transition, and the stakeholders in this study agree on this.

Significant emission reductions can be achieved, especially if large-volume structural materials are reused or designed for longer lifespan. As an example, a stakeholder hints that around every sixth major office building renovation—often driven by new tenant demands—can generate as many emissions as constructing a new building. By designing flexible buildings, preferably using wood components, much of this climate impact can be avoided when floor plans are changed. Additionally, maximizing the use of reused materials in both renovation and new construction projects is crucial.

This project focused particularly on challenges related to reuse and design for reuse of wood and CLT constructions in particular. The challenges identified in this research—particularly those related to logistics, certification, procurement, technical constraints, and regulatory frameworks—underscore the need for systemic change across the construction value chain. The most critical barrier, according to the stakeholders in this study, is the absence of an established logistics chain for reclaimed wood materials. Without an efficient system for collecting, reconditioning, storing, and redistributing materials, reuse remains costly and inefficient. To transition from small-scale initiatives to industrial-scale reuse, cost-effectiveness must be prioritized, as few clients are willing to pay a premium for circular solutions. Stakeholders emphasized that improving logistical frameworks would not only reduce costs but also make circular construction more feasible at scale. This aligns with findings by Nußholz et al. and Ritzén et al. [5, 6], which highlight the importance of infrastructure and supply chain coordination in enabling circular economy practices.

Additionally, the absence of CE-labelling and warranties for reused materials creates significant trust issues among industry actors. Currently, the responsibility for ensuring the quality and compliance of reused materials is unclear. Many contractors are hesitant to guarantee a structure built with components that lack standardized certification. In most cases, clients must assume this responsibility, which discourages widespread adoption of circular construction. Addressing this issue through standardized assessment protocols and regulatory clarity

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could enhance market acceptance and increase demand for reused timber. New standards developed in the "SirkTre" project is an initiative in the right direct [8], along with recent guidance from Boverket that outlines the requirements for reusing structural components and clarifies accountability [17]. However, this guidance is not yet widely known among stakeholders, limiting its impact on industry practices. Essentially, there are recent and ongoing projects relevant to the new guide that explore several issues from inventorying of wood quality for reuse to legal aspects.

Procurement and regulatory challenges further hinder the transition to circular construction. Existing building regulations and tendering processes are designed for linear material flows and short project timelines, making the integration of reused materials difficult. Current green financing mechanisms, such as green loans, primarily focus on energy efficiency and carbon reduction rather than end-of-life material reuse. Expanding the scope of financial incentives to include circularity considerations could drive demand for reused materials and encourage producers and structural design firms to develop more adaptable construction techniques.

The feasibility of reusing CLT elements was another key finding in this study. While technically possible, disassembly remains challenging due to the way CLT panels are currently mounted. In some cases, unscrewing the elements is difficult, requiring cutting instead, which reduces the material's potential for reuse. However, architects, CLT producers, and structural design firms agreed that designing and mounting CLT elements for greater flexibility could enhance their circular potential. The challenge lies in creating sufficient market demand for modular and reusable CLT solutions. Without client-driven demand, producers have little incentive to implement such changes.

An additional barrier to circularity is the perception that wood is already a sustainable material. Compared to concrete and steel, wood has a lower carbon footprint, which may reduce industry motivation to invest in further circular solutions. This perception risks limiting innovation in circular construction.

The stakeholders in this study were asked what role academia could play in supporting the industry in the transition to circular economy applications in wood construction. Three key areas emerged: (1) quantifying environmental savings through LCA to provide concrete evidence of circularity benefits, (2) demonstrating and developing technical and practical solutions and (3) facilitating collaboration among value chain actors and policymakers. The complexity of the transition means that no single stakeholder can drive change alone; instead, coordinated efforts between industry, academia, and regulatory bodies are necessary to develop viable circular solutions.

6 –CONCLUSIONS AND RECOMMENDATIONS

This paper is based on findings from an ongoing project exploring opportunities and developing tools to enhance circularity in multi-storey wood building construction in the Scandinavian context. The findings suggest that time and cost constraints are the main barriers to material reuse for multi-storey wood building construction. Stakeholders suggest focusing on improving the logistics chain for reused materials and ensuring CE-labelling. This underscores the need for collaboration between academia and industry to develop strategies to overcome the indicated barriers and thereby harness opportunities for a circular economy in multi-storey wood building construction.

Reusing wooden materials in construction projects is expensive because it is not yet common due to limited availability and legal restrictions. Logistics chains for reused materials need to be established. To achieve this, political incentives like subsidies for reused materials and green loans for building projects using reused materials are probably necessary. Additionally, procedures for evaluating materials for reuse, including assessing structural integrity and degradation, need to be standardized. Downstream, designing buildings for reusability and flexibility, is feasible and the first good examples of such buildings are emerging.

The perception that wood is already a sustainable material may limit industry incentives for further circularity. Bridging the gap between awareness and implementation will require coordinated efforts across policy, industry standards, and innovation in construction practices. Academia can play an important role here.

The findings of this research project will be utilized to support the wood construction industry and authorities working on policy changes at the regulatory level .To further decarbonize the building sector, preserving and reusing existing structures and materials must be prioritized, with Scandinavia well-positioned to lead this transition. While wood is often regarded as a sustainable building material due to its renewable nature and lower carbon footprint, significant barriers prevent widespread circularity applications in wood-frame construction.

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