



FORUM WOOD BUILDING BALTIC

24-25 APRIL 2025
RIGA TECHNICAL UNIVERSITY
RIGA, LATVIA

6TH FORUM WOOD BUILDING BALTIC
BOOK OF ABSTRACTS

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**RIGA TECHNICAL
UNIVERSITY**

6th Forum Wood Building Baltic. Book of Abstracts.

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The Book of Abstracts for the 6th Forum Wood Building Baltic comprises comprehensive abstracts of the research presented at the eponymous conference. The Forum Wood Building Baltic is the principal conference addressing architectural and engineering issues pertinent to wooden structures, including design for manufacturing and assembly, building physics, energy efficiency, and fire safety, in the Baltic Sea region. The conference is a part of the international organisation FORUM HOLZBAU.

The themes of the Forum Wood Building Baltic 2025 reflect the latest trends in European and Baltic wooden construction, and the accompanying exhibition titled Climate Neutrality in Europe and News in Sustainable Construction in the Baltic Region presents innovative wooden construction products.

FORUM HOLZBAU was established 25 years ago as a platform of leading universities for knowledge and technology transfer in timber construction, and achieves the goal through its pan-European program of conferences and exhibitions.

Previous Forum Wood Building Baltic conferences:

Tallinn, 26–28 February 2024

Vilnius, 30–31 March 2023

Riga, 9–11 May 2022

Riga, 16 May 2021 (online)

Tallinn, 27 February – 1 March 2019

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FORUM HOLZBAU

The 6th Forum Wood Building Baltic is part of the FORUM HOLZBAU network featuring a scientific conference and an accompanying exhibition of selected companies related to timber construction, held on 24–25 April 2025 at Riga Technical University, in Riga, Zunda krastmala 8.

The forum aims to build a bridge between the academic world and practice and present the latest international developments in timber architecture, engineering and technology to an audience of construction professionals – architects, engineers, contractors, housing organisations, planners, manufacturers and urban designers. Local and foreign experts participated in the conference, forming an international network of experts.

FORUM HOLZBAU is an association that promotes the use of wood in the construction industry with a particular focus on know-how transfer. FORUM HOLZBAU is a joint platform of the following universities: University of Rosenheim (GER), the Bern University of Applied Sciences (CH), the Aalto University of Technology, Helsinki (FIN), the Technical University of Munich (GER), the Vienna University of Technology (AUT) and the BCIT, British Columbia (CAN). In Latvia, FORUM HOLZBAU has a close cooperation with the Riga Technical University.

The conference focuses on the latest trends in European and Baltic wooden construction and is accompanied by exhibition titled Climate Neutrality in Europe and Sustainable Construction News in the Baltic Region, presenting innovative wooden construction products.

The Forum Wood Building Baltic 2025 is organised by the Institute of Architecture and Design, Institute of Civil Engineering, and Science and Innovation Centre of Riga Technical University in cooperation with FORUM HOLZBAU, in liaison with the Latvian Wood Construction Cluster and the Forest and Wood Products Research and Development Institute.

The future with wood

Timber construction is gaining popularity for a wide range of building types and sizes. As a natural cellular material, it is strong and light, making it easy to transport and erect. It can also be machined to very high tolerances, making it ideal for prefabrication. Recent advances in computer-controlled manufacturing and stronger and larger engineered wood products mean that timber construction can now achieve shorter programme times, often at lower overall cost, while providing a safer, cleaner and quieter environment on site. It is also our only renewable construction material, and it locks away carbon dioxide for the life of the building. The Forum – lectures and online networking where different organisations show their latest products and services – will be an opportunity for practitioners and scientists to meet and exchange experience and to learn from the best in the field.

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LATEST TRENDS IN EUROPEAN AND BALTIC WOODEN CONSTRUCTION

Arturas Sakalauskas

Annika Kadaja

Hermann Kaufmann



Arturas Sakalauskas

Architect and Senior Advisor at the Ministry of Environment of Lithuania, specializing in innovation. Bringing experience from both municipal and private sectors.



Annika Kadaja

Annika Kadaja is the CEO of Woodhouse Estonia, Europe's leading exporter of prefabricated timber buildings, known for its innovative approach to modular and sustainable construction. Recognizing the growing demand for sustainable and efficient construction solutions, Annika is actively leading initiatives to expand Estonia's success story.



Hermann Kaufmann

Prof. DI Hermann Kaufmann was born in 1955 in Reuthe, Bregenzwald (Austria) and comes from a family with a long tradition in the carpentry business. At that time, it was a matter of course to help in the parental business where he got to know the possibilities and the fascination of the building material wood and also the way of technical thinking that essentially moulded his work as an architect. The decision to study architecture was also influenced by his uncle Leopold Kaufmann, outrider in wood constructions and protagonist of the architectural development in Vorarlberg, under whom he learned as an intern the hand tools of an architect.

He graduated from the Technical University in Innsbruck and the Technical University in Vienna, where he was essentially shaped by his teacher, Professor Ernst Hiesmayr. After two years of practice, in 1983, he founded his own architectural office consortium with Christian Lenz in Schwarzach.

His attitude as an architect is influenced by the ideas of the classical modernism as well as by the debate on the context. The central theme of his work is the search for comprehensive answers to the sustainability of building and exploring the possibilities of modern wood constructions.

Numerous halls for carpentries and other businesses attest to his purposeful design concepts for wooden structures which are architecturally elaborated also effective for community halls. Besides numerous single-family houses the project list is completed by cautious renewals of old building substances in sensitive village contexts which proves his fine sense in handling with existing architectural culture and landscape. Housing constructions developed into a main task, especially in connection with wood and questions of energy as well as school buildings and public buildings.

His teaching career began in the winter semester of 1995/1996 as a guest lecturer at the Liechtenstein School of Engineering. This was followed by guest professorships at the TU Graz and the University of Ljubljana. In April 2002, he was appointed as a university Professor at the Faculty of Architecture at the TU Munich, where he headed the Chair of Timber Construction and Design until his retirement in spring 2021.

Shaping Policy of Bio-Based Construction and Prefabricated Renovation in Lithuania

Artūras Sakalauskas

Ministry of Environment of the Republic of Lithuania, Architecture and Construction Policy Group, Lithuania

Summary

Lithuania is taking bold steps to decarbonise its building sector by promoting the use of bio-based construction materials and prefabricated renovation methods. The government's Resolution No. 582 mandates a phased requirement for using at least 50 % renewable organic materials – primarily wood – in public buildings by 2028. In parallel, the country is piloting prefabricated panel renovation, an innovative approach using factory-made panels for energy-efficient upgrades of Soviet-era housing. These strategies are supported by a custom-built CO₂-equivalent assessment methodology and reinforced through public procurement incentives. As Lithuania develops a national life-cycle assessment (LCA) framework by 2029, environmental performance standards are expected to expand into the private sector, contributing significantly to the EU's 2050 net-zero goals.

Keywords: Bio-based construction; Prefabricated renovation; Wood architecture

As Europe accelerates its efforts toward a climate-neutral future, Lithuania is embracing bio-based construction materials and prefabricated renovation methods as key strategies to decarbonise the built environment. This dual-track policy approach not only addresses environmental imperatives but also strengthens the national construction sector and promotes circularity.

Lithuania's path toward bio-based construction has deep roots in European climate and resource policies. The 2012 EU Bioeconomy Strategy and the European Green Deal created a clear rationale for reducing emissions and increasing circularity, which has recognised that the construction sector contributes nearly 40 % of overall CO₂ emissions.

The Government of Lithuania's 2020 electoral program set a clear objective: all new public buildings must incorporate no less than 50 % bio-based materials. This ambition was formally institutionalised through Resolution No. 582, passed in July 2023, after extensive stakeholder consultations. The regulation excludes technically unfeasible building types (e.g., seaport infrastructure) and begins with buildings that do not involve sleeping accommodation due to fire safety considerations.

Wood and other organic materials are seen as both environmentally superior and structurally viable. They offer CO₂ sequestration potential and can replace imported, emissions-heavy materials. Importantly, the resolution also promotes adaptive reuse of vacant buildings, emphasising renovation over new construction where feasible. The legislation outlines a phased implementation.

- The phase **from 1 November 2024** applies to new public buildings with administrative, transport, cultural, educational (non-residential), and sports functions.
- The phase **from 1 January 2028** expands to include all public buildings, such as kindergartens and hospitals.

The directive promotes the use of wood and other renewable materials to lock in CO₂, cut embodied carbon, and support circular construction practices. The regulation allows up to 50 % flexibility based on technical feasibility, encouraging innovation without compromising ambition.

Following the adoption of Resolution No. 582, the Ministry of Environment launched a national effort to develop a robust methodology for defining and measuring the 50 % requirement. In response, **Kaunas University of Technology** led the development of a **CO₂-equivalent-based methodology**. The system compares the carbon sequestered in bio-based structural elements with the carbon emitted by conventional materials. To improve accuracy, an **index of difficulty** was introduced, accounting for structurally demanding solutions such as long-span elements.

The methodology disaggregates structural systems into distinct categories (e.g., timber, concrete, steel) and excludes components where bio-based use is technically infeasible: substructure and basement slabs, fire barriers and staircases, sanitary zones and emergency shelters, etc. The final formula expresses the ratio of CO₂ conserved by timber elements to CO₂ emitted by non-organic systems, presented as a percentage. This calculation will serve as the compliance benchmark starting on 1 November 2024.

Prefabricated Panel Renovation

Complementing the biogenic material mandate is the rollout of prefabricated panel renovation. This method targets Lithuania's vast stock of ageing Soviet-era apartment buildings and relies on factory-made wall and roof panels that

- are modular and standardised;
- contain at least 15 % bio-based material (excluding finishes, windows, and doors);
- include pre-installed components and require no scaffolding;
- meet Class B or A energy efficiency standards.

The approach promises faster, more sustainable renovations and will be tested in pilot projects across Vilnius and Utena. Compared to EPS-based insulation systems (+14.48 kgCO₂eq/m²), prefabricated panels with high bio-content can achieve up to -35 kgCO₂eq/m², contributing directly to climate targets and the circular economy where buildings become future resource banks.

In the Lithuanian context, bio-based construction materials are already proving to be one of the most effective tools for reducing CO₂ emissions in the built environment. For now, the state is taking the lead by encouraging their use through public procurement. Once the national methodology for life-cycle carbon accounting (LCA) comes into force in 2029, environmental performance requirements are expected to expand beyond public buildings and become an integral part of private sector construction, laying the groundwork for achieving the EU's 2050 net-zero targets.

Estonian Policy Calls for Innovation, but Estonian Industry Calls for Education

Annika Kadaja

Estonian Woodhouse Association, Estonia

Summary

Estonia's national strategies emphasise green innovation and digitalisation in construction – but these ambitions will remain hollow unless we invest in education and workforce development. The paper reflects on Estonia's timber construction success story and introduces the Woodhouse Academy – a new initiative led by the sector itself to bridge the gap between industry and policy goals, and practical workforce development.

Keywords: Wood construction; Modular construction; Vocational training; Education innovation; Workforce development

1. Introduction

Estonia is a small country with a big reputation in timber construction. With over 90 % of its wood buildings exported, Estonia ranks among Europe's leading producers of prefabricated wooden houses (540 mln export sales in 2022). The country has established a strong position in modular and element-based wood construction, delivering high-performance buildings to demanding markets like Norway, Sweden, Germany, and the UK.

This success is no coincidence. Estonia's forestry resources, digital capabilities, and entrepreneurial mindset have laid the foundation. However, a critical challenge is now becoming increasingly clear: while national strategies all over Europe call for innovation and climate-smart solutions, the industry is urgently calling for skilled people to implement them.

2. National policy and sector potential

Estonia's long-term construction strategy, together with the Rohetiiger (Green Tiger) initiative and national climate policies, outlines ambitious objectives for digitalisation, sustainability, and resource efficiency in the built environment. Key targets include:

- Seamless digital workflows throughout the design–construction–operation lifecycle
- Broader adoption of low-carbon and bio-based materials
- High-performance buildings that are energy-efficient, durable, and adaptable

Timber construction is uniquely positioned to support these goals. It enables prefabrication, reduces carbon emissions, and supports circular building practices. Yet materials and digital tools alone cannot drive transformation. Without a skilled and future-ready workforce, these ambitions may remain theoretical rather than transformational.

3. Current gaps and systemic challenges

The Estonian timber construction sector is facing a structural paradox. On one hand, companies are under increasing pressure to innovate – to adopt digital tools, meet environmental standards, and deliver ever more complex prefabricated solutions. On the other hand, they struggle to find workers with the right skills to support this transformation. Education programmes often lag behind industry needs, and traditional vocational pathways are not always agile enough to respond to the rapid technological and procedural shifts in the sector.

Higher education does not bridge the gap much faster. Even after completing a university degree, it can take up to two additional years of on-the-job experience for graduates to become truly competent in practical, real-world tasks. This highlights a systemic challenge: while our policy ambitions are forward-looking, our training pipelines are still catching up. The result is a growing mismatch between the pace of innovation and the readiness of the workforce needed to deliver it.

4. Woodhouse Academy – a sector-driven response

To address the growing skills gap in the timber construction sector, the industry launched the Woodhouse Academy (Puitehituse Akadeemia) in 2025. The pilot trainings are co-financed by the Central Baltic Programme 2021–2027, under the Wood for Youth project, which aims to strengthen young people’s competencies in timber construction as a future-oriented career path and to improve the quality and relevance of vocational education across the region.

Rather than a traditional education programme, the programme is a dynamic, modular training initiative co-created with woodhouse manufacturers and educational institutions. It aims to build a future-ready education ecosystem that evolves in step with industry needs and technological developments and enables faster entry of new talent into the sector.

The Academy’s core strengths lie in its comprehensive and practice-oriented approach. It covers the entire timber building value chain – from design and production to logistics – and focuses on hands-on competencies such as moisture safety, installation techniques, and factory workflows. Learning modules are designed to be flexible and stackable, making them suitable for workers, students, and engineers alike. In doing so, the academy fosters stronger collaboration between vocational schools, universities, and businesses, creating a continuous and adaptive learning pathway across all levels of expertise.

As much of the learning content is developed and delivered by industry professionals themselves, the Academy ensures unified and high-quality training materials that reflect real-world practices and current sectoral needs. The focus on practicality and digital delivery formats also significantly reduces the pressure on schools to secure specialist teaching staff. This setup allows the training to be easily integrated into various educational formats – regular curricula, elective courses, professional development programmes, and even micro-degree pathways – making it highly adaptable to different institutional and learner contexts.

Through Wood for Youth, the Academy contributes to cross-border curriculum development, practical training models, and teacher upskilling. It brings together industry, educators, and regional partners to jointly address the skills gap and promote timber construction as an integral part of the green and digital transition.

5. Conclusions

Policy visions must be matched by people with the skills to realise them. Only through sustained investment in education can we unlock the full potential of the green and digital transition in construction. But education itself must also evolve – especially at the professional level. This is where the industry must step up and take ownership. The key question is not whether innovation is needed, but how far companies are truly willing to go to invest in the people who will shape their future.

Contemporary Architecture: Think in Wood

Hermann Kaufmann, Professor

HK Architekten | Hermann Kaufmann + Partner ZT GmbH, Austria

Development

Timber construction has undergone major changes over the past thirty years. Not only has the development of new construction products, systems and engineering technologies been coupled with the rapid modernisation of building processes to make the material relevant for our time, but it is clear to see that wood can offer significant solutions for the future of the built environment. Many surveys support this contention: wood is increasingly seen as a material that offers hope for an endangered world.

System

Wood is often touted as a building material ideally suited to luxurious and unusual solutions. Yet, wood is an everyday material, and therein lies its importance for the future. What is needed here are not highly individual experiments; instead, clear, concise communication regarding the development of exemplary systems and a broader availability of expert knowledge in the field are the order of the day.

Flexibility

Working with wood demands expertise and a well-founded knowledge of its properties. Wood sets limits, yet allows manifold applications. It is precisely these challenges that make designing and building with wood so fascinating and make successful projects such an exciting source of inspiration for the future.

Sustainability

The most compelling argument for constructing with wood is the fact that this is a material produced by energy from the sun and absorbs and stores CO₂ from the atmosphere. Wood can be adequately disposed of and recycled and requires little energy to be worked – compared to metals, plastics and mineral-based construction materials.

Building material

An environmentally friendly building does not necessarily have to be made of wood. However, if the house is built in a region where wood is available in abundant supply, it is certainly the most environmentally friendly method. Building materials should not be transported great distances. Consequently, it is recommended to build with regionally available materials

Environmental aspects

An environmentally friendly house must meet certain criteria. It must be located near public transit. Its architectural design must reflect the landscape and its context. Its construction must consume a minimum of resources while limiting environmental pollution as much as possible. The house must be energy efficient, and demolition must be possible without polluting the environment. Individual components of the house must be designed with different maintenance cycles, permitting easy renovation.

An energy-efficient building must be very compact. The building envelope must be well insulated. All materials used for construction must be locally available and, whenever possible, renewable. An environmentally friendly house must be built to last for a long time and adapt to future needs.

Apartment buildings

Numerous built examples have shown that it is possible to construct multi-storey apartment houses in wood. Such projects were often built on the client's initiative, in an attempt to promote innovation. We are in a critical phase now. Will it be possible to make use of these experiences for the benefit of the broad public? Is there sufficient demand for such apartment buildings, and can this demand make an impact upon the market? Will wood engineering successfully establish itself in the market? Is it possible to convince the rigidly structured, market-dominating general contractors to consider the use of wood construction routine?

Costs

Costs are determined primarily by the magnitude and duration of the construction process. The central question is always: How fast can a structure be built, and at what level of quality? This highlights one of the most striking advantages of timber construction, for no other material can be prefabricated so extensively and with such attendant reductions in construction time. Additionally, quality is improved through the standardisation of the production of construction elements. The time-honoured traditions of prefabrication in carpentry have developed into a highly industrialised form of construction that is capable of delivering high-quality, flexible and contextually sensitive buildings.

Economy

Due to the relatively low demand at present, the timber construction industry is still quite fragmented; however, a few highly professional, technologically advanced firms have established themselves on the market. These companies are capable of carrying out even the largest projects anywhere in Europe. There are also a number of excellent small enterprises which can execute demanding, on-site building tasks. Worldwide, the Alpine Zone is currently the region most skilled in timber construction – the result of longstanding craft traditions that are being supported by intensive and coordinated research into methods and materials.

The future

Compared internationally, Vorarlberg is very advanced; however, we have not yet reached our goal. Exemplified by the community centre in Ludesch, which was our pilot project, it became evident how important it is to also take into account the energy used for constructing a building. This 'grey energy' can be reduced by three-quarters of the energy used for conventional buildings by carefully selecting the building materials. At slightly higher costs, 'healthy buildings' can be produced, which pollute the environment as little as possible, while ensuring a healthy indoor climate by avoiding toxic construction materials.

We must examine common building practices more closely and strive more intensely to ensure sustainability. I do not consider this a limitation; I see it as a chance to generate architecture for a broad audience.

Aspiration

Architects must strive to develop ideas beyond the specifications of their clients. In other words, architects should not be instrumentalised by clients for the sole purpose of wish fulfilment. As dedicated experts, architects should add value to the planning process. Only then can progress in architecture and construction become a reality. The conditions must be discussed and interpreted at early stages of planning, so as to develop new ideas.

Evolution

Based upon my experiences, the issue is not about promoting a vision, but rather fuelling an evolution. I have always sought to apply the principles of sound craftwork and a basis of well-founded technical knowledge to every new step I take; through this approach, I have been able to avoid the plight of the visionary. The true aim is to pursue the path of precise and consistently applied steps. Only this approach can lead to sustainable development.

WOODEN ARCHITECTURE PROJECTS IN BALTICS

Mikelis Putrams

Marija Katrīna Dambe

Lore Köster



Mikelis Putrams

Architect, co-founder of MADE arhitekti, winner of the Latvian Architecture Award 2012, Grand Prix 2023. Certified passive building designer. Worked in "Plot" and "B.I.G." Denmark. He has lectured at European universities and architectural forums, and has been a jury member for architectural competitions. His work has been nominated several times for the Mies van der Rohe Prize for European Architecture. The Pitrags Stop project was shortlisted for the New European Bauhaus Prize and was awarded the Gubbio Prize (2024). The most well-known realised works – Salaspils Kindergarten, Dailes Theatre forecourt, Wooden Office Building in Lizums, Saldus School of Music and Art, etc.



Lore Köster

She studied Interior Design with a focus on Architecture at the Technical University of Applied Science in Rosenheim (THRO). While working in Munich for an architect's office she had a focus on executive and detail planning, tender work and project management.

After coming back from where she worked for a Swiss Company for two years, Lore participated in the introduction of computer aided design at THRO and founded her own Architectural office.

From 1992 till 1996, she was a Lecturer in design at the SISH Biel University of Applied Sciences, Switzerland. Since 1997, she has planned different projects in timber construction.



Marija Katrīna Dambe

Marija Katrīna Dambe is an architect and owner of NOMAD architects, as well as a lecturer at Vidzeme University of Applied Sciences. She has studied architecture at the Academy of Fine Arts Vienna and sustainable architecture at the Norwegian University of Science and Technology. Currently she does her PhD studies at the Estonian Academy of Arts with research focus on the changing role of an architect in sustainable and participative construction processes. Marija's primary expertise is in the circular economy. Some of most notable projects include research and co-development of the 3cycle system, circular pre-renovation audit for Riga Municipality, as well as designing the Latvian National Pavillion at the 19th International Architecture Exhibition – La Biennale di Venezia.

Salaspils Kindergarten – Questioning the Building Code

Mikelis Putrams

MADE arhitekti, Latvia

Summary

The Salaspils kindergarten is a two-storey all-wooden structure with a total area of ~3000 m². Engineering knowledge alone is not enough to realise such a wooden building in Latvia. The Latvian building code LBN201-15, which specifies fire safety requirements for buildings, needs to be changed. The Salaspils kindergarten has better occupant safety than any other kindergarten, but it does not comply with the Latvian building code.

Keywords: Timber architecture; Fire performance of timber structures; Energy performance of buildings; Material toxicity

1. Introduction

During the design process MADE arhitekti team was selecting priorities that would reflect the qualities of an environmentally sound building for kids. Energy efficiency, low-emission structure and no toxic materials in the interior of the building. It seemed clear and logical to carry out the technical design according to the priorities, unfortunately, we found out that, actually, the existing building code is limiting the possibilities to execute the project in the best possible quality according to sustainability targets.

2. Methods

2.1. Energy efficiency

There are no restrictions for low-energy solutions in Latvia. Mostly, the challenge is to balance the architectural and spatial qualities with technical and energy requirements. AV ratio, which makes the foundation for good results, usually creates several challenges regarding natural light quality in rooms and logistics of spaces. It is not difficult to plan a compact volume and simple building block; it is challenging to realise architectural qualities within it.

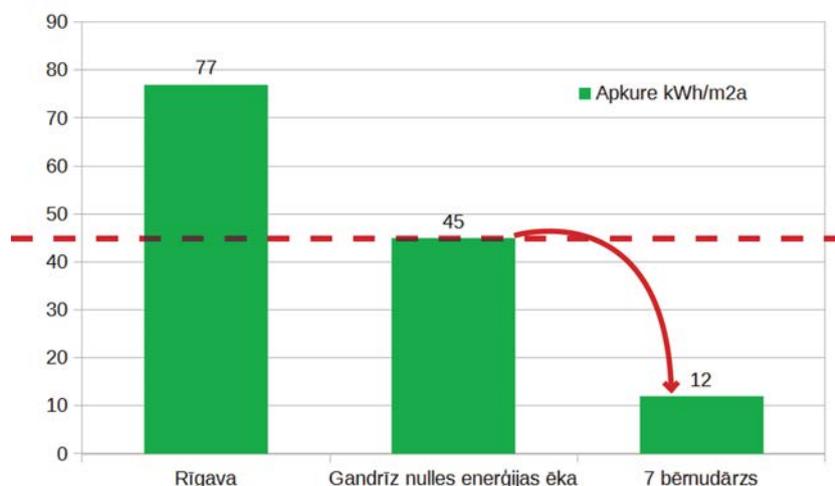


Figure 1. Comparison of energy use for heating of three buildings: normal municipality building renovated in 1992, nearly zero energy standard in Latvia, Salaspils kindergarten PH standard.

2.2. Low-emission structure

It was obvious that to reduce the CO₂ emissions, the timber structure would be the most efficient strategy. Not only are engineered timber production emissions lower than production of steel and concrete. The embodied carbon in timber structures captured during the growth of timber makes the material a carbon storage. The Latvian building code LBN201-15, which specifies fire safety requirements for buildings, does not approve two-storey buildings for kids in timber. During the design phase, we understood that if we follow the building code, we will end up in a mediocre sustainability level, we would also be compromising several innovations in energy efficiency and consequently also reducing indoor air quality. Thanks to the competent design team, we were able to propose deviations from the building code, which were approved by the state fire department technical commission.

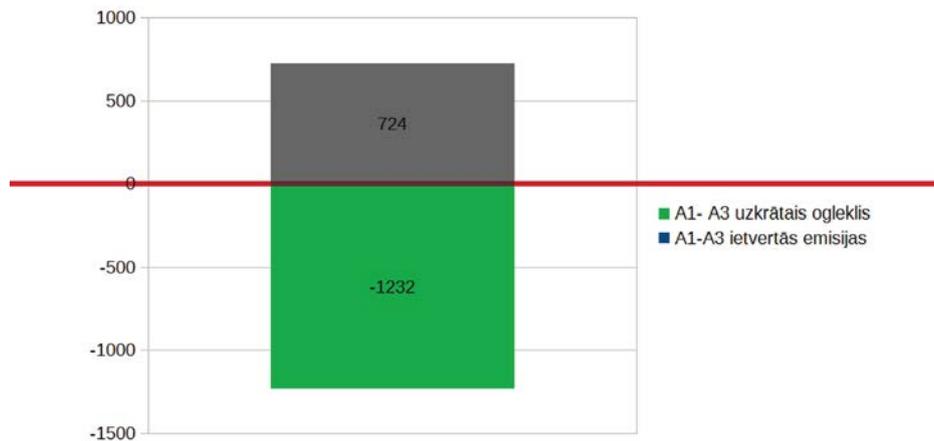


Figure 2. Emissions and embodied carbon of Salaspils kindergarten.

2.3. No toxic materials

When designing a building for kids, it is easy to sell the idea of a healthy and safe environment and materials. Many times during the design process, the maintenance and durability issues tried to prevail. The unforeseen challenge in executing toxic-free interior was during the construction process, when many additional materials not selected in the original design came into play. Glues, base coats, fixing materials, fire-safe materials, additional materials for repairs, and even the toxic substances to clean wood surfaces. There is an enormous amount of different materials in the building industry that are toxic and used without the approval of designer. The special approval procedure, created by the municipality, helped to carry out the toxic material control on the building site.



Figure 3.
Classroom with no toxic materials.

3. Results and discussion

In order to fulfil the several quality criteria at the same time, a holistic and multi-faceted design and engineering approach is necessary. This asks not only for an open-minded engineering team but also the understanding and tolerance of the more sophisticated design process and design approval procedures.

4. Conclusions

We can obviously see many qualities in the new Salaspils kindergarten building that align with European climate goals and well-being standards of future buildings. Therefore, the building code should be revised to give architects more freedom and responsibility.

5. Acknowledgements

We thank:

our client – Salaspils municipality,
State Fire Department's Technical Commission,
Fire Safety Consultant Edvins Grants,
Structural Engineer Gatis Vilks,
all architects, engineering team, consultants and advisers.

Designing for Circularity: The 3Cycle Modular Timber System in Estonian Public Architecture

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¹ *NOMAD architects, Latvia*

Summary

This paper introduces the 3Cycle modular timber system, developed to enable circular and adaptable construction in public architecture. Grounded in design-for-disassembly, the system supports reuse at multiple scales. Three Estonian case studies – built, in planning, and conceptual – demonstrate its application and flexibility. The results suggest that integrating circularity into the system level allows architects to focus more on spatial quality, lifecycle scenarios, and design detail, while still achieving low-carbon outcomes.

Keywords: Circular construction; Modular construction; Toxfree; Wood architecture; Cultural heritage; Reversible buildings; Systems thinking

1. Introduction

1.1. Current understanding of sustainability in Baltic construction

The construction sector's impact on the environment through CO₂ emissions, resource consumption, and waste generation is not a new topic. These issues have been discussed in public and brought to government attention already for multiple decades. However, recent construction sites across the Baltics show that only a handful of 'lighthouse' projects engage seriously with these issues, while the rest still operate in a 'business as usual' manner. While energy efficiency is often emphasised as a unique sustainability feature, it is typically achieved by meeting baseline regulatory requirements rather than exceeding them. Meanwhile, embodied carbon, resource extraction, and end-of-life scenarios are largely overlooked. Although circular economy principles are often presented as novel or complex, they were in fact the norm for centuries, only displaced by linear economy models in the past hundred years.

1.2. Carbon stock and manner of construction

Timber buildings serve as temporary carbon sinks, storing sequestered CO₂ from tree growth. However, this benefit is limited unless the building's components are reused beyond their initial lifecycle. To achieve this, a systematic shift toward circular design is necessary, ensuring that materials remain in circulation well beyond the standard 20–50-year use cycles. A case can be made for reusing prefabricated timber elements and modules that are largely standardised and fit a wide variety of building typologies.

2. Development of the 3Cycle system

The 3Cycle system was developed with a focus on creating an open prefabricated timber construction system that follows the principles of design for disassembly. The system operates on three nested disassembly levels: room modules, building elements (e.g., walls, slabs), and individual components/materials. Each level enables targeted reuse or adaptation, extending both building and material life cycles, thus it contributes to a substantial shift in future emissions and waste. The system is compatible with production lines in most Baltic factories that produce volumetric timber modules.

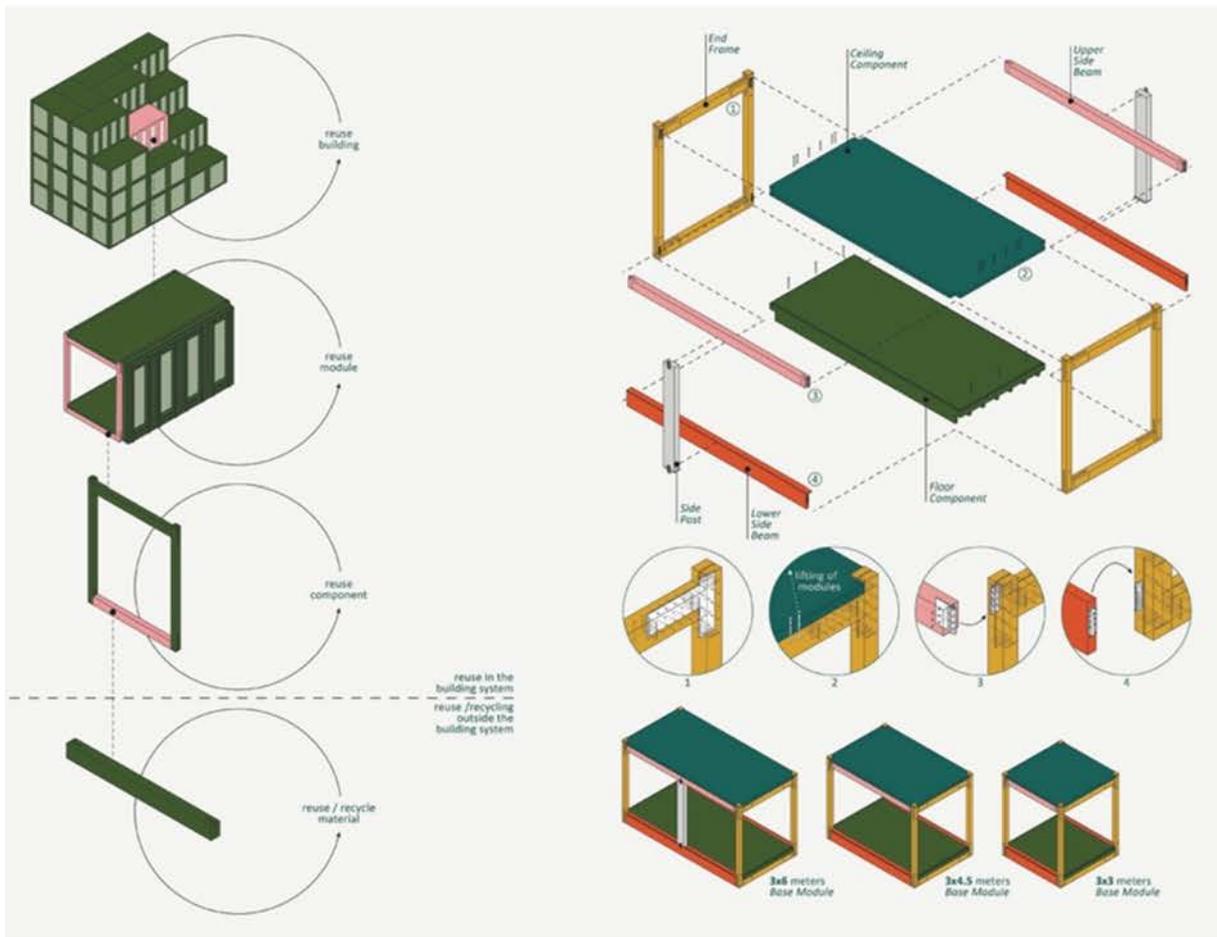


Figure 1. Illustration from the 3Cycle guide (above). Assembly of Elektrilevi training centre in Kiili, Estonia (left).

3. Three case studies in Estonia

3.1. Elektrilevi training centre in Kiili, Estonia

The Elektrilevi training centre is a two-storey building with classrooms and a workshop for electricians. The key objective was to fully implement the 3Cycle circularity principles and gather structured feedback from the manufacturer and the on-site assembly team.

3.2. Manufaktuuri kindergarten in Tallinn, Estonia

The Manufaktuuri kindergarten is a 3015 m² project currently in the planning phase, located within a historic urban setting. The design engages with heritage-sensitive context through careful massing and material choices, while integrating toxfree construction principles – a topic still underexplored in mainstream practice. The project also anticipates future adaptations, ensuring long-term spatial and technical flexibility.

3.3. Proposal for a school in Kajamaa, Estonia

The Kajamaa preschool competition proposal combined volumetric modules from the 3Cycle system with prefabricated timber elements, testing a hybrid approach to off-site construction. The project focused on enabling highly transformable interior layouts that support inclusive, contemporary early childhood education. The case provided a setting to investigate how modular design principles can be reconciled with programmatic complexity and long-term spatial adaptability.

4. Conclusions

The 3Cycle system shows that a modular, open-source timber method rooted in design-for-disassembly can address key challenges in public buildings: circularity, low carbon, material health, and adaptability. The Estonian case studies highlight that early alignment with manufacturers, regulators, and end-users is crucial. For architects, the system embeds core circular goals, freeing up time for design detailing, lifecycle planning, and architectural expression. For public authorities, it allows experimentation within existing regulatory frameworks.

5. Acknowledgements

We thank Renee Puusepp, Eero Tuhkanen, Kristo Kalbe, and Marc Fuzellier.

Sustainability for Timber Construction – Students' Residential Quarter CampusRO

Lore Köster, Dipl.-Ing. (FH)

Planungsbüro Köster, Stephanskirchen, Germany

1. Project presentation

The students' residential quarter CampusRO has the character of a lighthouse and sets new standards in many respects.

An open competition was held to find an urban planning and architectural concept that meets all of the client's criteria and expectations. A special living space has been created for the new generation of students in an architecturally, technically, digitally and sustainably optimised system.

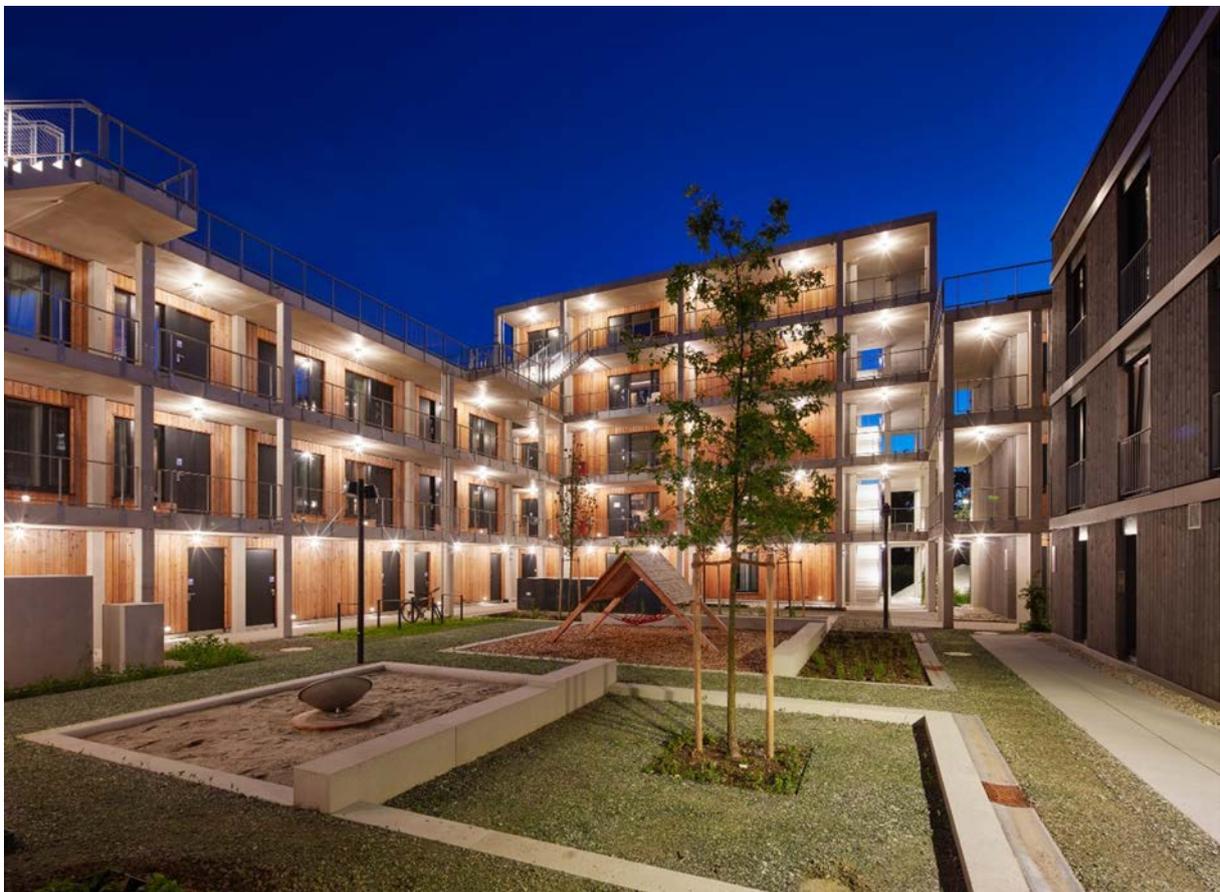


Photo: Sigurd Steinprinz

1.1. Urban planning competition

- Motto: To live in a special place, to learn, to work together and to mature personally
- Innovations and concepts according to this motto
- Sustainability

- Construction: Resource Timber
- High degree of prefabrication
- High energy efficiency (passive house standard) and building technology
- Efficiency and flexibility (floor plans)
- Lighting and sunlight
- Barrier-free access
- Digital planning – BIM model

1.2. Design idea of the winning team ACMS Architekten

The idea was to create a village character with individual little houses for the students, but lots of places for communication.

The individual little houses are lined up in rows and stacked on top of each other at different heights.

Inner courtyards were created between the building complexes.

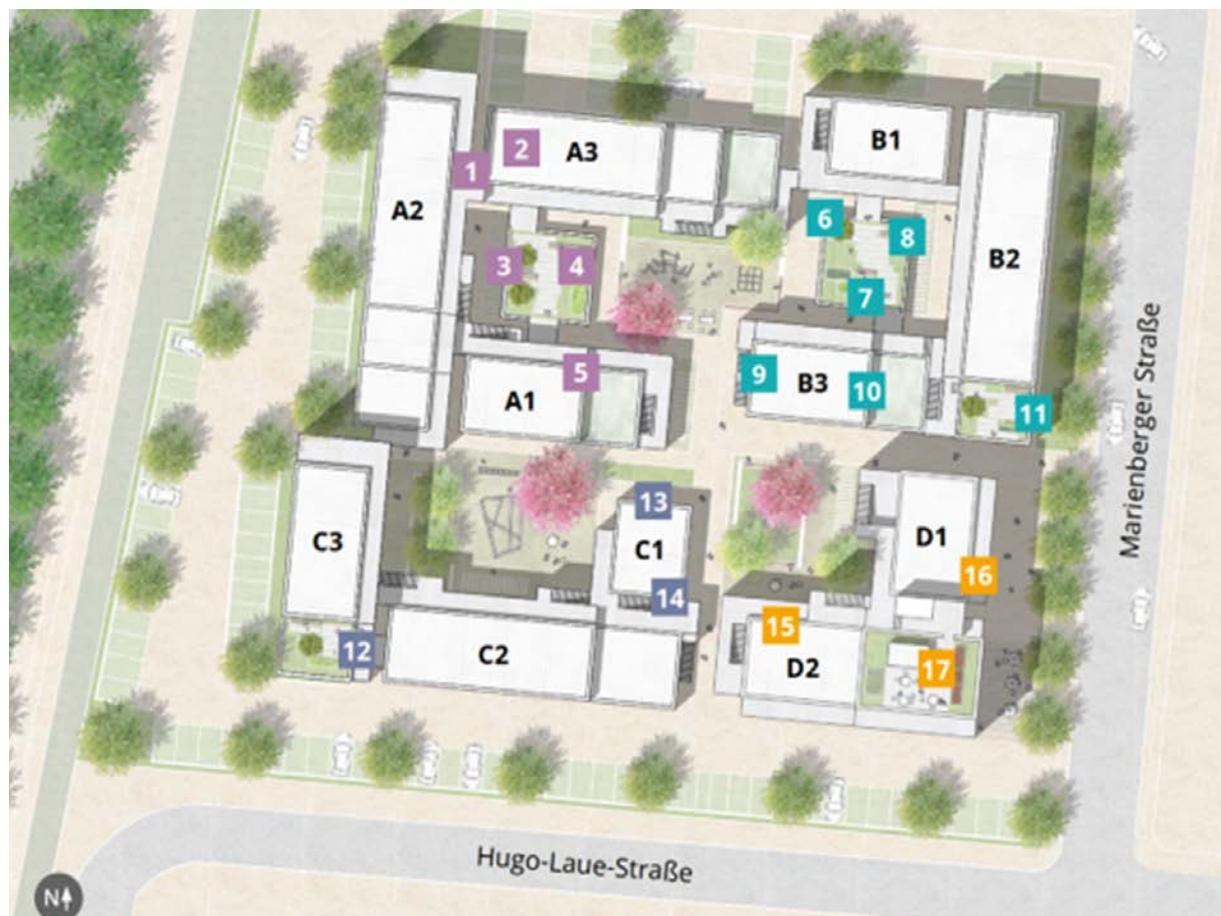
All apartments are accessed via arcades that connect all buildings to each other.

Roof terraces with green communication zones were created on top of the roofs.

Common rooms for meeting, learning, cooking and fitness complement the concept.

The result was a stacked village with vertical and horizontal communication zones.

1.3. Site plan



Source: based on ACMS Architekten, Wuppertal

2. Energy concept

- Efficient building shell
- Battery storage
- Heat supply – district heating
- Decentralised ventilation
- Summer thermal insulation

3. Open BIM Model



4. Construction



Photos: Huber & Sohn

5. Sustainability certification in Platin

Source: MNP Ingenieure, Lübeck

6. Summary and conclusions

- Aspiration to build a lighthouse project with a high quality of stay
- Urban planning competition for an excellent and innovative architectural and landscaping design
- Definition of requirements – in competition text
- Involvement of all expert planners right from the start
- Collaborative partnership of all planners
- Obligation of an auditor for certification on the part of the client
- Obligation of a BIM manager on the part of the client
- Voluntary agreement to digital planning – open BIM model

POLICY FOR SUSTAINABLE CONSTRUCTION

Sara-Tuuli Siiskonen

Petri Heino

Heinrich Köster



Sara-Tuuli Siiskonen

Sara-Tuuli Siiskonen, a researcher at the Finnish Environment Institute in the Unit of Built Environment Solutions, specializing in promoting low-carbon buildings and international climate reporting for the construction sector.



Petri Heino

Petri Heino is a forester, graduated from the University of Helsinki, Forest Products Marketing as the main subject. Currently he is working as an external consultant in the European Wood Policy Platform (woodPoP) for the Ministry of the Environment of Finland. He is also a partner in a start-up company m2impact Ltd.

As a Director of the Wood Building Program at the Ministry in Finland in 2016–2023 he initiated and co-chaired the European Wood Policy Platform. His previous assignments include various tasks in the Finnish Forest Industries Federation, WoodFocus, Finnish Timber Council, Finnish Timber Trade Association, University of Applied Sciences of Kymenlaakso, and Jaakko Pöyry Consulting.



Heinrich Köster

After graduating in 1978, Köster worked for twelve years in an engineering office for wood technology and worked internationally. From 1990 to 1996, as Professor, Dean and Head of the Research and Development Department, he was responsible for setting up what is now the University of Applied Sciences for Wood Technology in Biel in the Swiss canton of Bern. In 1996, Köster returned to Rosenheim University of Applied Sciences, where he teaches in the Faculty of Wood Technology and Construction in the field of corporate planning.

He has been a member of the university's Executive Board since 2002 and President since 2009. During his time in office, the number of students has doubled, he has initiated numerous degree programmes, repositioned continuing education and research and development at the university, initiated the construction of the student centre and the technology park and founded the Mühldorf am Inn, Burghausen and Traunstein campuses.

Development of the National Emissions Database, CO2data

Sara-Tuuli Siiskonen, M.Sc. (Tech.)

Finnish Environment Institute, Finland

Summary

Interest in building LCA grew as building energy efficiency improved and energy production began to decarbonise, leading to the need for the creation of a uniform basis for building LCA. CO2data was developed to provide essential data for building lifecycle assessments. Hundreds of environmental product declarations and numerous studies were analysed to create general emission data representing Finland. CO2data offers open and impartial data that can be integrated into LCA tools in line with national legislation. It supports low-carbon construction practices by providing crucial information to understand and monitor the lifecycle emissions of buildings.

Keywords: Emission database; Building materials; Energy efficiency; Carbon footprint; Building LCA

1. Introduction

In the transition of buildings towards low-carbon solutions, regulation has primarily focused on energy efficiency. However, with improvements in energy efficiency, interest has broadened to encompass the entire lifecycle emissions of buildings, particularly how the building materials can be regulated to achieve even more ambitious emission reductions in the building sector. The Finnish Ministry of the Environment's 2017 Low-Carbon Roadmap drove the goal to regulate buildings' carbon footprints throughout their lifecycle. Effective regulation relies on a trinity composed of the calculation method, calculation tools and emission data.

Although several tools for building LCA were available, existing data had deficiencies for consistent calculations. It is essential to have access to emission data that reliably represents materials used in Finnish conditions. This led to the development of the national emissions database, CO2data. The development of the CO2data began by searching for answers to the following questions: What is the intended purpose of the database? How will it be used? Who is it intended for?

2. Methods

To establish a national emissions database, it was crucial to consult various stakeholders and incorporate their perspectives to identify suitable methods. The development started with stakeholder interviews to define suitable content and technical implementation. When the framework for the content and implementation of CO2data was clarified, the content creation began, utilising various methods depending on the needs.

Several methods have been used for data compilation, primarily consisting of analysing Environmental Product Declarations (EPDs), international databases, various studies, and statistics. By utilising that information, a value is generated for the emissions database to represent the generic emission value of each input, aiming to represent the solutions typically used in Finland. Since the creation of emission data is case-specific, the assumptions and analyses for all inputs are detailed in background reports. These reports aim to explain to users why a particular value was chosen and to help replicate the process when updating values.

3. Results and discussion

The result of the work is a national emissions database, developed and maintained transparently, utilising feedback from users and stakeholders. The emissions data presented in the database represent generic inputs and assumptions reflecting Finnish conditions, enabling anyone to perform consistent lifecycle assessments for buildings.

As a result, we have found answers to the questions.

- **What is the intended purpose of the database?** The database functions as one part of a triad, which consists of the calculation method, calculation tools, and emission data. The database provides generic emission data for building LCA when more precise official information is not available. More precise official information is represented by product- or product group-specific EPDs, which enhance the competitive advantage of a good product, as the goal is to increase the number of EPDs.
- **How will it be used?** The content of the CO2data is openly available and can be accessed through the user interface or downloaded in Excel format. Since the database content is also utilised in calculation tools, a machine-readable JSON file format has been developed to facilitate data integration.
- **Who is it intended for?** The database serves all interested parties as it is free and openly accessible in several languages. It can be used for multiple purposes, from producing comprehensive LCA calculations to examining the emission data of individual products.

4. Conclusions

The fact that the calculation method has been developed simultaneously with CO2data has posed certain challenges to the development of the emissions database. On the other hand, simultaneous development has enabled the integration of some necessary changes into the database with a simplified effort. The role of collaboration must be emphasised, as the correlation between the calculation method, calculation tools, and CO2data is clear. Therefore, the overall impacts of the considered changes are best comprehended through open discussion. Collaboration with industry stakeholders is also extremely important, which is why the added value provided by feedback must be highlighted. Feedback has served as a tool to communicate changes in the industry to the database development, but it has also assisted in understanding the various use cases of the database.

Data alone is not enough; it has also been recognised that documentation must be provided to users in conjunction with the service. The database is intended to answer questions, not raise them. We have learned that systematic archiving of documentation is an essential part of maintaining such a database in the long term.

The ultimate goal is to reduce emissions from the construction sector by providing information. Now that we have a database to meet the needs of building LCA, it is time to direct our interest to the following questions: What can we learn from the accumulating data of LCAs? How will changes in the emissions database be reflected in the LCA results?

5. Acknowledgements

On behalf of the entire CO2data development team, I would like to thank the stakeholders involved in data creation and the collaborative efforts from different industries, whose activities have significantly supported our development work. Our deepest gratitude goes to the Ministry of the Environment for their guidance and funding.

WoodPoP – a European Initiative to Advance the Sustainable Use of Wood

Petri Heino

Co-Lead of TWG Building; European Wood Policy Platform (WoodPoP), mandated by the Finnish Ministry of the Environment, Finland

Summary

WoodPoP is an innovative policy dialogue platform that brings together all relevant actors to advance the sustainable use of wood. It develops wood-related policy solutions, measures and recommendations to strengthen the wood-based circular bioeconomy.

Keywords: Wood policy; Governance; Building; Research; Innovation; Education; Communication

1. Towards a circular bioeconomy

As a renewable resource, wood and wood-based products from sustainably managed forests provide an immediate solution in mitigating climate change. By substituting fossil-intensive and non-renewable materials and fuels, sustainable wood has become a key factor in the transformation towards a CO₂-neutral and circular bioeconomy.

In this context, the European Wood Policy Platform (WoodPoP), initiated by Austria and Finland, facilitates the exchange and collaboration between administration, industry and research. Through this exchange, WoodPoP strengthens the role of wood as a renewable resource and actively contributes to shaping framework conditions for sustainable wood-based value chains.

Since December 2023, the Secretariat of the European Wood Policy Platform has been hosted by the International Union of Forest Research Organisations (IUFRO), leveraging its global scientific network to provide policy options.

The Secretariat is funded by the Austrian Forest Fund with support from the Federal Ministry of Agriculture, Forestry, Regions and Water Management (BML).

2. Operating model of WoodPoP

WoodPoP provides a dedicated forum for multilateral policy, knowledge and experience exchange between public and private actors. The platform actively contributes to shaping the framework conditions for sustainable wood-based value chains and develops wood-related policy solutions, measures and recommendations. Stimulating innovation, exchange, and cooperation is an important part of the collaboration, as well as increasing the visibility of the added value of enhanced wood use.

Through the exchange between policymakers, industry and research, the role of wood in the mitigation of climate change is strengthened, and the clean, just and competitive transformation of Europe is supported.

The work is organised through specific technical working groups (TWG) with a lead by a national public body, such as a ministry. Five TWGs are operating: governance, building, research and innovation, education and vocational training, and communication. The work in each TWG is designed to encourage and facilitate the dialogue and vivid exchange by focusing on the following WoodPoP objectives within the framework of individual TWG:

1. CONNECT: Identify issues, address data gaps, and promote processes for knowledge creation.
2. COLLABORATE: Report on the progress to the whole platform at the expert group

meetings and provide recommendations to the WoodPoP high level meeting for wider and political actions.

3. EXCHANGE: Discuss challenges and trade-offs, develop solutions for sustainable policy making.

Participation is open to national and regional ministries, the private sector, interest groups and research organisations, regional organisations and networks, as well as invited experts.

3. Results and discussion

The European Wood Policy Platform (WoodPoP) currently reunites 100 governmental representatives from 27 pan-European countries as well as around 150 different experts from stakeholder organisations, research and industry. The meetings take place in hybrid mode in annual high-level meetings, which is a decision-making body, expert group meetings (twice a year) to share knowledge throughout the platform, and TWG meetings (monthly or quarterly).

Highlights of some of the activities in the TWG:

- TWG governance. A Wood Policy Paper (A Wood-Based Circular Bioeconomy for a Sustainable Europe) was formulated and adopted by WoodPoP high-level representatives in Brussels in 2024.
- TWG building. Topics covered in the meetings are: fire regulations, EU policies regarding construction, insuring buildings, building technologies and public procurement policies.
- TWG innovation and research. A report on the European R&D capacity and a funding program analysis for SMEs in the wood sector is being developed.
- TWG education and vocational training. A policy brief dedicated to the perspectives from the New European Bauhaus Academy on upskilling and reskilling the wood construction sector will be published.
- TWG communication. Analysis of the existing wood architecture (and related) competitions and awards has been carried out, and development of a WoodPoP prize is ongoing.

4. Conclusions

The European Wood Policy Platform (WoodPoP), initiated by Austria and Finland in 2022, is successfully facilitating exchange and collaboration between public and private stakeholders in order to develop policies for the sustainable wood-based value chains and end-uses.

More information: woodpop.eu



Figure 1. The high-level meeting of WoodPoP in Brussels on 6 November 2024.

The Future of Timber Construction Facing the Challenges of Industry 4.0

Prof. Dr. h. c. Heinrich Köster | President

Technical University of Applied Sciences Rosenheim, Germany

Summary

The future of our buildings will be produced through realisation and design of AI, automation using robotic systems and prefabricated 2D and 3D modules, considering the right materials.

1. Introduction

The Presentation will have the following content:

- Current situation and environmental policy
- New materials and semi-finished products (engineered wood products)
- Advanced building Technology
- Advanced production technology from the aspect of automation
- Training and continuing education in advanced building aspects

2. Methods

When considering the automation solutions described above, it is clear what a significant role comprehensive data generation, preparation, and provision plays. For the implementation of fully automated processes, it is essential to create data from construction plans and details for all materials and components that contain the necessary information for all processes.



Advanced Wooden Buildings.

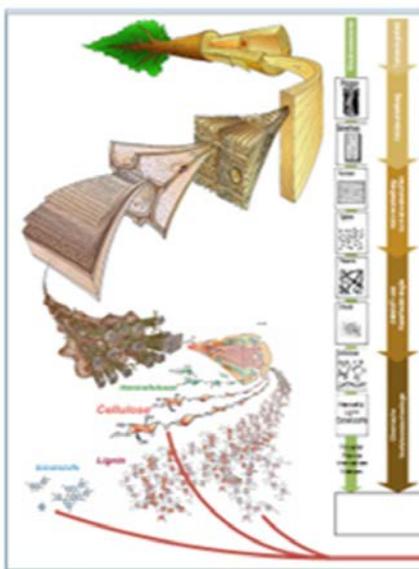
Circular use of Wood and Engineered Wood Products.



Prefabrication: past and today. Advanced Production of Housing Elements.

3. Results, discussion and conclusions

Automation and productivity can be significantly increased through automation, thus making living more affordable.



Solidwood...
vener..
chip based



Fiber-
composites



Lignin and
hemicellulose

CONTEMPORARY WOODEN ARCHITECTURE

Tom Svilans

Martin Looser-Frey

Jaakko Torvinen



Tom Svilans

Project Associate at Omtre AS and Researcher at the Royal Danish Academy, Tom Svilans is an architectural designer, consultant, and researcher exploring digital fabrication, materiality, and emerging technologies. His work focuses on digital design across the timber value chain – from forestry to construction – and methods of integrating new imaging and information-communication technologies in the design and fabrication of engineered timber elements. As a consultant, he specialises in the computational modelling, design development, and fabrication coordination of complex timber structures.

He obtained his PhD from the Royal Danish Academy, Centre for IT and Architecture (CITA); Thesis titled “Integrated material practice in free-form timber structures” developed with industrial partners Blumer Lehmann AG (Switzerland) and White Arkitekter (Sweden). He is Assistant Professor in Digital Timber and Researcher at the Royal Danish Academy since 2021 and Project Associate at Omtre AS since 2024.



Martin Looser-Frey

Martin Looser-Frey graduated from the Bern University of Applied Sciences, as well as from the University of St.Gallen having studied in the School of Business, Law and Social Sciences. His professional activities have started since 2004 as a carpenter, progressing to project management and construction site management. Since 2019, he is a Member of the Board at “Blumer Lehmann Group”, Division Manager Free Form Timber Construction dealing with international clients.



Jaakko Torvinen

Jaakko Torvinen is an award-winning Finnish architect and PhD researcher at Aalto University. After graduating in 2021, he focused on naturally shaped wood in architecture and construction. He teaches wood architecture and runs his own studio.

Digital Timber Practice

Tom Svilans, Research Fellow¹, Project Associate²

¹ *Royal Danish Academy, Denmark*

² *Omtre AS, Norway*

1. Introduction

This paper describes a developing material practice that engages the complexity of timber directly through digital methods. It presents a series of projects that explore how new forms of non-destructive assessment, computational modelling, and information logistics can support a design approach that is materially specific, spatially ambitious, and fabrication-aware.

It begins with a set of digital design modelling tools that relate fabrication and material properties of glue-laminated timber beams to architectural models. This becomes the basis for managing the intermingling of architectural and material complexity and leads to a series of experiments that leverage high-resolution X-ray computed tomography (CT) scanning for performance-driven design – the RawLam experiments. The digital methods prototyped there are developed further into non-destructive assessment methods for timber components and more detailed studies of the computational mechanics of wood. The information complexity of linking material stock with design components across different scales in a production environment is taken up further by the Marina Spa Prototype project, where individual beams are composed of many small pieces of flooring off-cuts. These concerns are further discussed in the context of ongoing work at Omtre AS with the processing of both non-standard tree geometries and reclaimed timber materials. Finally, it offers several perspectives that have evolved throughout these projects and that continue to guide the evolution of this digital timber practice.

The main point of the study is the idea that, to leverage the strengths of wood in construction and to push the limits of its application in architectural projects, more detailed methods of assessment are needed, combined with more extensive information integration throughout its value chain – from forest to architectural element. The use of high-resolution digital sensing and computational modelling methods offers much promise towards these aims.

2. Developing a digital timber practice

2.1. Material practice – integrated material practice in free-form timber structures

The development of the material practice begins with an interest in the glulam blank – an object in-between standardised raw material and finished construction component (Svilans, 2020). The hypothesis is that, by looking closer at the processes involved in the production of glue-laminated timber beams and by developing modelling methods that integrate key constraints and data points into early-stage design processes, new architectural and construction opportunities emerge.

By aligning geometric definition with fabrication logic, the aim is to enable tighter coordination between material characteristics and architectural intent (Svilans, 2021). These methods allow spatial and structural complexity to be informed by and responsive to the underlying material composition. From a design perspective, it extends the remit of the designer across the timber value chain into the space of glulam manufacturing and tailored material composition.

2.2. Performance and behaviour – RawLam

The RawLam experiments are inspired by looking further back along the timber value chain and investigating how high-resolution CT scanning, already used in industrial sawmilling for yield optimisation, can inform performance-driven design. The volumetric scan datasets provide a detailed insight into the composition of individual logs, mapping specific material features such as knots, the pith line, the sap line, and growth rings.

RawLam speculates about the usage of this mapping to match precise mechanical performance demands in engineered timber components with specific parts of the log, as a way to more thoroughly utilise the entirety of the sawn log. This resource-driven design integration connects the CT scan of the log with the final in-situ construction element. RawLam envisages 'whole-tree usage', where the entirety of the log can be re-allocated and reconstrued into highly-specific engineered elements, while preserving some of the 'rawness' of the original tree by incorporating bark and wane (Tamke et al., 2021; Svilans, Tamke, Ramsgaard Thomsen, 2022). Ongoing research extends this approach to reclaimed timber and develops CT-based non-destructive evaluation methods for structural assessment and design integration.

2.3. Information logistics – Marina Spa Prototype, Omtre AS

The Marina Spa Prototype explores the use of reclaimed timber offcuts in the production of complex structural components (Svilans et al., 2024). Developed as a scaled-down version of a previously unbuilt architectural proposal by Helen and Hard Architects, the prototype is constructed from interconnected curved beams, each assembled from short segments of wood flooring off-cuts. These segments are visually assessed, sorted, laminated into curved blanks, and re-machined into their final geometries.

The project demonstrates how well-defined information logistics can bridge largely unpredictable and irregular material inputs with individually formed architectural elements. It requires precise control of material sorting, digital modelling, and fabrication data to manage high material variability and specificity, as well as tight construction tolerances. The success of the project depends on the tight control of information between the initial sorting and cutting of the individual off-cut segments and the detailed machining of the individual beams.

At Omtre AS, ongoing work is addressing the challenges in sorting and managing reclaimed timber elements, particularly in scaling up such processes to industrial levels. On the one hand, the integration of 3D scanning and robotic machining allows the processing of non-standard forms such as tree roots into digitally-designed building elements. On the other hand, more generic products such as reclaimed timber studs present different challenges purely in terms of scale and quantity of throughput. As with the Marina Spa Prototype, assessment of the individual timber element and its tracking through the subsequent processing steps are key success criteria; however, the challenges are compounded by the greater variance in properties, dimensions, and characteristics of reclaimed wood.

3. Conclusions and perspectives

The presented projects outline a digital material practice grounded in a deep engagement with the complexity and heterogeneity of timber and its processing in architectural production. At its core, it addresses the assessment and modelling of timber across several scales of engagement and the integration and interconnection of information between disparate actors and processes throughout its value chain and lifecycle.

The work spans diverse production contexts – from large-scale productions and industrial sawmills to local and sometimes ad hoc setups. As such, the practice must be aware of and able to operate within both. Each presents different challenges and characteristics, yet can be fundamentally impacted and leveraged by digital methods of assessment, modelling, and integration. Likewise, the practice must operate both in contexts that are highly interconnected, automated, and systematised, as well as contexts that are more direct

and straightforward. Across these scales and types of production context, heterogeneity needs to be addressed. The challenges at a material level are well-known; however, this heterogeneity extends into other, broader aspects of timber harvesting, processing, and manufacturing, including the heterogeneity of information that must be successfully synthesised and aligned with architectural demands. Finally, the projects demonstrate how digital tools and models can move beyond being representational devices and toward becoming active and operative tools within the design process. When embedded with material data and linked to fabrication workflows, they enable new forms of coordination between material behaviour and design intent. Together, these perspectives continue to shape a digital timber practice that is at once computational and materially grounded.

4. Acknowledgements

The study presented here was initiated during a PhD project entitled *Integrated material practice in free-form timber structures*, which received funding from the European Union's Horizon 2020 Research and Innovation Programme under the Marie Skłodowska-Curie grant agreement No. 642877.

RawLam 1 and 2 were initiated and funded as part of the Material Imagination project, led by Aarhus Arkitektskole. The RawLam 3 demonstrator was commissioned by the Umeå Bildmuseet.

The on-going work with non-destructive assessment using X-ray CT scanning is part of the Eco-Metabolistic Architecture (EMA) project at the Royal Danish Academy, which has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 Research and Innovation Programme (grant agreement No. 101019693).

The Martina Spa Prototype team consisted of Helen & Hard Architects (Siv Helene Stangeland, Reinhard Kropf, Håvard Auklend, Simon Aeschmann), Design-to-Production GmbH (Martin Antemann), the Royal Danish Academy (Tom Svilans), Aarhus Arkitektskole (Niels Martin Larsen, Anders Kruse Aagaard, Matthias Klith Hardarson), Creation Holz (Hermann Blumer and Christoph Meier), and Winther A/S (Morten Winther). Special thanks to Dinesen Floors A/S and the Danish Architecture Centre (DAC).

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Free Form Timber Constructions (Almost) Limitless

Martin Looser-Frey

Blumer Lehmann AG, Gossau, Switzerland

Summary

The diversity of free form timber structures or free form timber claddings is almost limitless as soon as we can produce the blanks out of our wonderful material, wood. Lots of raw materials, wood-based materials and engineered timber standard products are available on the market, but how smart can they be used and where are the limits of using timber and engineered wood materials?

The combination of traditional, proven construction methods and state-of-the-art manufacturing methods in timber construction is increasingly being rediscovered. This combination, in turn, creates new opportunities to recognise and achieve previously unattainable goals.

For example, traditional dowelled beams, which were used to build timber bridges in the early 18th century, can be found in new timber construction projects. Dowelled beams, combined with the latest construction planning and digital planning and manufacturing methods, are used today to build huge, self-supporting and wide-span free-form gridshell roofs.

The enthusiasm for combining the advantages of tradition and high-tech is fascinating and drives us to constantly develop new ideas.

1. Free form tree structures

1.1. Various options to build a free form tree structure

A tree structure can be built in various ways, and overall, we can say that 'the design follows function' is a principle in the development.

The design intention of the architect is to initiate an iterative planning phase, which needs to be done until the execution. All design and structural requirements, as well as other framework conditions, must be taken into account and included in several planning loops.

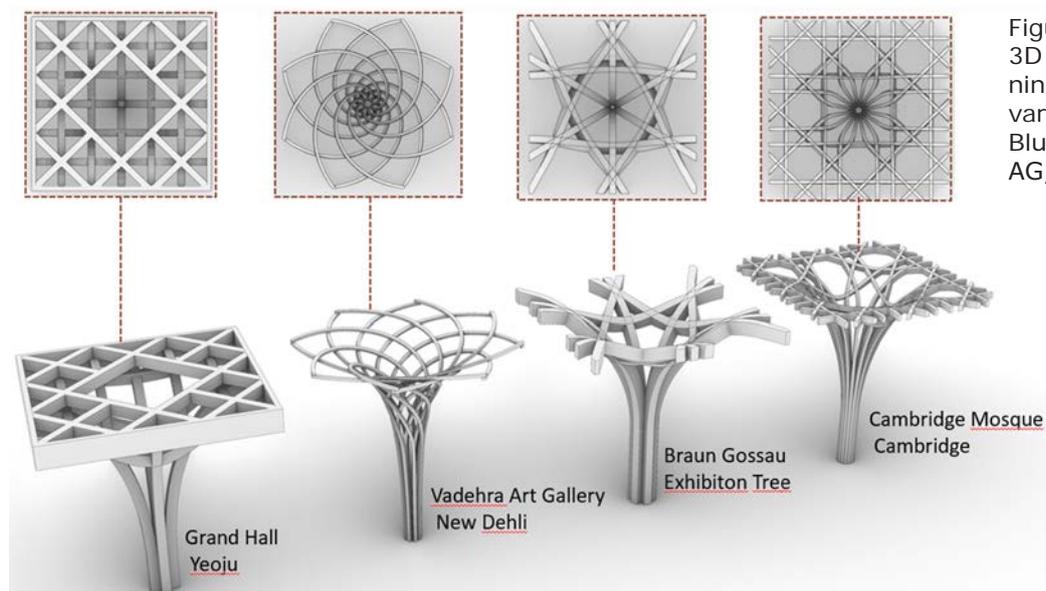


Figure 1.
3D Rhino planning models in various designs, Blumer Lehmann AG, Switzerland.

1.2. Grand Hall and Haesley Nine Bridge's golf resort

The rooftop of the Grand Hall at Haesley Nine Bridge had to be designed very strong because of the fact that it is covered by a glass roof which has a lake on it. Furthermore, in the stainless steel pods in the centre of each, a tree has been planted.

So, the load impact of the glass facade and the water, as well as the steel pods and the trees, led to this strong and robust loadbearing 1-layer tree structure.



Figure 2. Grand Hall of Haesley Nine Bridge's Golf Resort, Shigeru Ban Architects, Paris.

1.3. Cambridge Mosque

The very big advantage, to be part of the development team of Marks Barfield Architects, helped to design the very optimised structure accordingly to the optimum of the static.

Although the dome, in the centre of the prayer hall of the mosque, weighs more than 5 tonnes, it can be supported by this very filigree-designed single-layer tree structure.

The structure is built with single- and double-curved glulam beams and CLT deck on top.



Figure 3. Cambridge Mosque Prayer Hall with Dome, Marks Barfield Architects, London.

2. Free form grid shell structures

2.1. Swatch Headquarters, Biel, Switzerland

One of the biggest and most ambitious free form gridshell roofs is truly one of the Swatch headquarters in Switzerland. Due to the designer's wish, all the technical installation, even the sprinkler system had to be implemented in the 5-layer free form structure.



Figure 4. Swatch Headquarters (right), Omega Museum, Cité du Temps, Shigeru Ban Architects, Paris.

2.2. Nujuma, Ritz Carlton Guest Hub, Red Sea, Foster & Partners

In the structure of the Guest Hub, which has mainly the function of a shading system, the smaller 3-layer free form gridshell acts as a secondary structure within the frame of the primary structure. The gridshell (secondary structure) was handcrafted and produced without 5Axis-CNC Milling.



Figure 5. Nujuma Guest Hub, Ritz Carlton, Foster & Partners, London.

2.3. Wisdome Stockholm by Elding Oscarson Arch.

The striking design by Elding Oscarson and Florian Kosche emerged as the winner of an architecture competition. The roof geometry spans a footprint of 25 m x 48 m, without columns. The free form structure is based on a grid system of LVL beams.

The dome below the vaulted roof is made from cross-laminated timber. A requirement of the architecture competition was that timber be used in the construction, in particular cross-laminated timber (CLT) and laminated veneer lumber (LVL).



Figure 6. Wisdome Stockholm, National Museum of Science and Technology, Elding Oscarson Architects, Stockholm.

Roof grid shell structure with dowelled LVL panel strips. For the main roof, the timber construction engineers at SJB Kempter Fitze opted for a lattice-shell structure with criss-crossing LVL beams. With interlocking dowel joints and the help of cutting-edge planning tools, these were connected to form a double-curved grid. The differently vaulted roof construction is supported around the edge by 24 solid columns that are made from block-laminated LVL with dimensions of 60 cm x 80 cm and 60 cm x 60 cm.

The columns are connected rigidly to the approximately 1.20-metre-high concrete base. To limit the horizontal deformation of the roof support structure, tensioning rods are integrated into the wooden columns, to which a considerable pretensioning force is applied after assembly. A solid edge beam is arranged on the column heads to enclose the free form construction all the way round.

3. Free form with curved CLT

3.1. Atrium HQ Blumer Lehmann, K&L Architects, ICD Stuttgart

To build the atrium of Blumer Lehmann's Stammhaus, the architects of K&L Architects and the Computational Design of the ICD Stuttgart, as well as our internal parametric planning specialists, had the intention to put a hollowed out tree trunk – ausgehöhlter Baumstamm – through all the floors with curved CLT.



Figure 7. First model of the HQ study/design idea of the atrium with curved CLT boards, K&L Architects, CH.

The function of the atrium is the vertical connection with the stairs as well as vertical ventilation to ensure a natural ventilation of the building and the possibility for natural during-night-outcooling.

The curved CLT was produced by Blumer Lehmann itself as a cross-laminated multilayer board, and it provides a new element to the architects for stunning and excellent wooden designs.



Figure 8. Atrium of the Headquarters of Blumer Lehmann AG, Switzerland, Blumer Lehmann, Switzerland.

Architecture with Organically Shaped Wood – Pikku-Finlandia and Other Designs

Jaakko Torvinen

Finland

Summary

This paper outlines the use of whole wood in architecture, examining projects that employ naturally shaped wood to enhance design and sustainability in construction. This approach connects historical building methods with modern digital and fabrication technologies, promoting biodiversity and forest resource efficiency in the building industry.

Keywords: Wood architecture; Whole wood; Natural form; Industrial building

1. Introduction

The advent of industrialisation in wood construction has led to widespread standardisation, emphasising homogeneous materials and sidelining the traditional use of naturally shaped wood. Current wood construction is predominantly based on standardised wood construction products, while historically, wood was also used in its natural form (Zwerger, 2023). The projects discussed here aim to integrate organically shaped wood forms into modern architecture. These designs emphasise the ecological benefits and material efficiency of using whole wood, retaining the natural characteristics and carbon storage inherent in each tree, and creating unique architectural atmospheres.

Promoting organically shaped wood construction not only supports resilient forestry practices but also offers architectural designers an opportunity to explore the aesthetic and structural potential of non-standard wood forms. The designs celebrate the inherent beauty of natural wood, championing a sustainability-focused approach that integrates forest materials into urban landscapes.

2. Methods

Projects include public buildings, pavilions, and experimental structures, utilising naturally shaped wood to challenge conventional norms. Through these projects, it is studied how to use the organically shaped wood in architecture and modern construction: identifying the material sources for naturally shaped wood within the current wood value chain; developing methods to integrate technically non-standard wood elements into industrial construction systems; and leveraging contemporary technology in design and fabrication processes.

3. Results and discussion

Pikku-Finlandia, situated near Töölönlahti Bay, serves as a temporary venue during the renovation of Finlandia Hall from 2022 to 2025 (Figure 1). Embracing circular economy principles, the building is designed to be relocated in 2026, when it will serve as an extension of a high school in northern Helsinki. This project arose from collaboration between Aalto University, the City of Helsinki, and Finlandia Hall operators and was initiated during a graduate-level design studio at Aalto University.

The building spans 123 metres by 25 metres and is arranged on a regular orthogonal grid with a total of 95 pine columns. Among these, 56 columns function as primary load-bearing elements, while the remaining ones serve aesthetic and non-structural purposes. Additionally, 36 columns are situated outside the building, creating a striking colonnade that complements the exterior canopy and terrace. This integration of whole Scots pine logs, with branches intact, demonstrates nature's architectural influence, offering a forest-like atmosphere amid the urban setting.

Covering a total area of 2,720 square metres, Pikku-Finlandia incorporates untreated pine trunks, which symbolise the Finnish national romantic tradition and provide structural stability alongside conventional materials like CLT panels and glulam beams. The design prioritises sustainability, featuring reusable and recyclable materials supporting Helsinki's carbon-neutral goals. Inside, adaptable spaces are configured to accommodate diverse event requirements, showcasing efficient energy use and innovative material conservation.

Katve Pavilion, built by Aalto University's Wood Program, uses trees sourced from a single Finnish forest stand, peeled with jet washing, 3D scanned for joint designing, and fabricated with CNC. The pavilion's construction involved extensive documentation to inform subsequent projects like Pikku-Finlandia. This hands-on approach exemplifies the interconnectedness of concept development and practical application in architectural design.

Experimental structures were conducted at Aarhus School of Architecture: two experimental projects explored the use of 6-axis robotic fabrication with irregularly shaped wood. The first mock-up featured the assembly of curvy trunks into linear elements using handmade markings as guidance for the robot. By installing a 3D scanner in the processing of a 6-axis robot, it was ensured that the position of an irregularly shaped workpiece was always according to the machine tool. The second project involved splitting an oak trunk into four parts, optimising the position of cuts along the trunk to preserve the branches in all pieces to create four structural components to be connected inside-out.

These experiments demonstrated the feasibility of combining organic forms with high-tech fabrication processes, offering insights into potential industrial-scale applications. The success of these projects was showcased in several exhibitions: the curvy trunk pillar was featured at the New European Bauhaus Festival in Brussels in 2024 and COP29 in Baku; the split oak structure was exhibited during the Helsinki Design Week's "Designs for the Cooler Planet" in 2024, and it will be part of a permanent exhibition at Finlandia Hall.

The projects collectively advocate for why whole wood should be considered a viable material in architecture, emphasising its role in promoting biodiversity and enhancing material utility. Reintroducing naturally shaped wood into the built environment aligns with sustainability principles while offering new design possibilities.



Figure 1. Pikku-Finlandia next to Finlandia Hall, Helsinki. Photo by Mikael Linden, 2022.



Figure 2. 6-axis robot cutting an irregular wood trunk, Aarhus School of Architecture.

4. Conclusions

While biodiversity and forest resilience might initially appear unconnected to architectural practice, there exists a profound link between forestry management and the building industry's material demands. Trees and species that do not conform to established production processes are frequently regarded as having lower economic value, subsequently relegated to biofuel or pulp manufacturing. This valuation system encourages the development of monocultural forest plantations, thereby impacting the biodiversity conservation efforts of forest owners (Takala et al., 2022).

The projects presented demonstrate the transformative potential of whole wood in architecture by blending historical methods with contemporary technology. This aims to increase the ecological benefits and create a new kind of wood architecture, as well as drive systematic changes in the way materials are valued in the construction industry. Finding potential uses for a broader range of tree types may have the potential to intervene in current cycles of forest management and product utilisation. While the non-standard characteristics of whole wood are often assumed to be challenging in industrial processes, the research suggests that these issues are not insurmountable when using careful planning and incorporating scanning technologies with digital fabrication. Nevertheless, questions about the structural behaviour of these elements remain to be investigated. Previous studies, such as those by Wolfe (2000), have demonstrated that unsawn wood can have higher bending strength than comparable sawn elements. Further research could be directed at incorporating the unique structural behaviours of these elements.

5. Acknowledgements

Pikku-Finlandia Design team: Jaakko Torvinen, Elli Wendelin, Havu Järvelä, Pekka Heikkinen, in collaboration with Architects NRT.

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Instructors: Pekka Heikkinen, Philip Tidwell, Laura Zubillaga ExternalAdvisors: Kari Virtanen (Nikari Oy), Meinrad Rohner (Alppisalvos Oy), Martti Kolkka (HAMK), Juho-Pekka Virtanen (3D-scanning, Aalto Dept Built Envrn.).

Experimental structures: Jaakko Torvinen, Jakob Sieder-Semlitsch, Jens Pedersen, Anders Aagaard, Niels Martin Larsen, Matti Kuittinen.

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THE USE OF WOODEN STRUCTURES

Imants Trezuns

Renee Puusepp

Jānis Sauka



Imants Trezuns

Imants Trezuns, Mg. sc. ing., certified structural engineer. Timber frame panel and modular technology expert with experience in the industry for more than 18 years. Chief innovation officer at company Nordic Homes, Lecturer at Latvia University of Life Sciences and Technologies.



Renee Puusepp

Renee is an architect and a construction technology entrepreneur; a practitioner and researcher.

His team at Creatomus Solutions makes digital configurators – tools for designing and constructing low-impact modular buildings. As a senior researcher in the Department of Architecture at the Estonian Academy of Arts, he leads the research of open-source modular building systems - Pattern Buildings. Renee's current focus is on connecting the two technologies in order to bridge the gap between design and production of buildings.



Jānis Sauka

Jānis Sauka is an architect and one of the founders and partners of "MARK arhitekti" since 2006. He is the co-author of the restoration and reconstruction of the castellated part of Riga Castle for the Latvian National History Museum. He is currently involved in the design of the Riga Philharmonic. His work is distinguished by its respect for the cultural and historical context and precise contemporary solutions.

Is 'Pre-fabricated' the Solution?

Imants Trezuns, Mg. sc. ing.,^{1, 2}

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² Lecturer at the Latvia University of Life Sciences and Technologies, Latvia

Summary

Is 'pre-fabricated' the solution to the growing need for new, sustainable and energy-efficient housing? The pre-fabrication concept has been around in many forms for some time, but it seems that the market is still waiting for the next big innovation in this sector. At the same time, the market players are not ready to embrace the efficiency of manufacturing, but can you imagine that your smartphone or your car would come to you in an unassembled form, and you would hire a local contractor to assemble it afterwards?

1. Introduction

Traditional construction methods are increasingly challenged by inefficiencies, high waste production, rising costs, and sustainability demands. At Nordic Homes, we believe prefabrication, done right, is the way forward. Since 2010, we have specialised in multi-storey wooden and hybrid buildings, delivering over 60 000 m² using a system that aligns architecture with industrial precision and sustainability.

2. Methods

Our approach combines:

- **tailored prefabrication** of 3D modules using timber (CLT, GL), steel, and concrete;
- **digital twin technology** (SEMA, Revit, BIM LOD 400) for precision planning and MEP coordination;
- **in-house engineering and manufacturing** for controlled quality;
- **high pre-fabrication rates** (>85 %) to minimise onsite activity;
- **modular design flexibility** that respects architectural vision;
- **efficient logistics planning** to optimise transport and site assembly.



Figure 1. Timber frame and glulam structure modules for attic floors.

3. Results and discussion

By applying this method:

- **error costs** are reduced by over 10 %,
- **inefficiencies** drop by 15–20 % through better planning and coordination,
- **CO₂ emissions** are reduced by up to 60 % (even achieving negative emissions with timber modules),
- **waste** from construction is cut by more than 50 %,
- **construction time** is reduced by 30–50 % compared to traditional methods.

Notably, we emphasise avoiding over-standardisation – every project remains unique. Projects like the student housing in Liverpool, a luxury apartment building in Battersea, and a 5* hotel in Iceland illustrate real-world performance and adaptability.

4. Conclusions

Prefabricated modular construction is not a compromise – it is an upgrade. When hybrid systems and digital precision meet architectural creativity, the result is faster, greener, and smarter buildings. Prefabrication is not about mass production; it is about **mass customisation** that benefits clients, the planet, and the built environment.

5. Acknowledgements

We acknowledge the contribution of our dedicated team at Nordic Homes across Latvia, Germany, and Iceland, as well as our engineering and sales partners.

Airtightness Performance of 3Cycle Modular System

Renee Puusepp, CEO, PhD^{1,2}

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² *Estonian Academy of Arts, Estonia*

Summary

This study evaluates the airtightness and acoustic performance of two buildings constructed with the 3Cycle modular timber system. The first is a school typology with timber-frame modules, and the second is a small house with CLT walls. Blower door tests show both case studies achieve excellent airtightness, roughly half of typical new-building values. The findings highlight how design details (timber-frame vs CLT wall panels) influence performance, demonstrating the 3Cycle system's capability to deliver high-performance, energy-efficient modular buildings.

Keywords: Pattern buildings; Modular timber construction; Airtightness; CLT

1. Introduction

Modular off-site construction is increasingly adopted to improve building quality and sustainability. The 3Cycle building system, developed at the Estonian Academy of Arts, uses standardised timber modules and connections to enable flexible, circular buildings that can be easily reconfigured or disassembled.

Constructing modules in a factory environment can enhance quality control, leading to improved airtightness compared to site-built methods (modular.org), which is critical for energy efficiency in cold and temperate climates. However, it is essential to verify that such novel systems meet performance expectations in practice. The aim of this study is to compare their measured performance against typical benchmarks and to evaluate how different wall build-ups (timber frame vs cross-laminated timber) influence the results.

2. Methods

Two completed buildings constructed with the 3Cycle modular system were examined. **Case 1** is the Elektrilevi Training Centre (406 m² GIA), a double-storey educational building composed of factory-made CLT/glulam modules with balloon walls (Figure 1a).

Case 2 is a small country house (47 m² GIA) with similar modules but walls made of CLT (Figure 1b). Both structures were assembled in Estonia in 2023–2024. The 3Cycle system principles were applied in both, meaning a high degree of prefabrication and standardised detailing.

All measurements were carried out according to relevant standards. Airtightness was tested via blower-door pressurisation (ISO 9972:2015) on each building after construction. The resulting air leakage rate at 50 Pa pressure difference, normalised by building envelope area (qE50), was recorded. These results were compared to the design targets and building code requirements.



Figure 1. Prefabrication of modules for the Elektrilevi Training Centre (left) and a country house (right) in a factory.

3. Results and discussion

Both case studies demonstrated high levels of airtightness. The Elektrilevi Training Centre achieved a measured air permeability of $qE50 = 1.300 \text{ m}^3/(\text{h}\cdot\text{m}^2)$, while the Tähe CLT micro-house achieved $qE50 = 1.16 \text{ m}^3/(\text{h}\cdot\text{m}^2)$.

The training centre's result is roughly 2 times tighter than the baseline for non-residential buildings ($2.5 \text{ m}^3/(\text{h}\cdot\text{m}^2)$), and about 13 % better than the design intent (declared value). The micro-house's result is even more notable: about 3.4 times tighter than the small-building baseline of $4 \text{ m}^3/(\text{h}\cdot\text{m}^2)$ and 23 % better than its design target. Such airtightness levels approach those required by passive house standards, indicating excellent envelope sealing.

4. Conclusions

Both timber-frame and CLT-based modules can attain very low air leakage – attention to sealing details in design and prefabrication is critical. CLT panels simplify achieving airtightness (acting as an air barrier by themselves), whereas timber-frame walls naturally provide cavity insulation and separation but need careful membrane installation for airtightness.

5. Acknowledgements

The author acknowledges EstNor OÜ for collaboration in constructing the case study buildings and Lufter OÜ for carrying out airtightness tests.

Integrating Mass Timber in Cold Storage Construction: A Case Study from Latvia

Edvins Grants¹, Janis Sauka²

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² *Architect at MARK, Latvia*

Summary

This paper presents a pioneering case of a wooden cold storage facility constructed in the Gauja National Nature Park in Latvia. The case study focuses on the Latvijas Finieris tree nursery Zābaki. Designed and executed by a wood processing company in collaboration with architects and researchers, the building exemplifies the integration of business, science, and education. Key challenges addressed include thermal performance, fire safety, moisture behaviour, and architectural integration in a sensitive landscape. Experimental data and modelling work contribute to the understanding of mass timber's behaviour in refrigeration environments

Keywords: Thermal performance; Fire safety; Moisture behaviour; Architectural integration in a sensitive landscape



Figure 1. Latvijas Finieris tree nursery "Zābaki". Photo: Latvijas Finieris.
Architectural design: MARK Arhitekti.

1. Introduction

The project marks the first known instance of a fully wooden cold storage building in Europe. Initiated by Latvijas Finieris, a wood processing company with over two decades of experience in timber construction, it reflects a regional commitment to sustainable building solutions. The Zābaki nursery building serves as a functional facility for seedling storage, a demonstration site for wood-based construction, and a research platform.

Situated near the Gauja river in a protected natural park, the complex comprises a production building, administrative unit, storage facilities, and technical areas. A key architectural challenge was reconciling industrial use with the scenic environment. Timber was used as the primary load-bearing material (CLT panels and glulam), including in roofs and walls. The layout follows a square-shaped plan, referencing historical Latvian farmsteads, and features green roofs for visual integration.



Figure 2. Administration building of the Zābaki tree nursery: (left) exterior view, (right) interior view. Photo: Latvijas Finieris. Architectural design: MARK Arhitekti.

2. Research

From a research perspective, the primary question was whether mass timber could perform in a cold, high-moisture environment without becoming a durability risk. Cold storage for seedlings requires maintaining constant sub-zero temperatures, leading to complex thermal flows, especially in transitional seasons. Simulations revealed that conventional insulation could trap moisture; instead, exposed mass timber envelope assemblies were found to be more suitable.

3. Results and discussion



Figure 3. Sapling cold storage building of the tree nursery Zābaki : (left) exterior view, (right) interior view. Photo: Latvijas Finieris. Architectural design: MARK Arhitekti.

A study was initiated using CLT samples conditioned in climate chambers under four different regimes. The thermal conductivity was measured across 80 samples (Norwegian spruce, 3-layer, 20 mm lamellae). Results showed that:

- thermal conductivity is highly sensitive to equilibrium moisture content;
- manufacturer-specific values are significantly lower than normative assumptions;
- end-grain orientation at joints increases heat transfer, requiring special detailing.

Fire safety compliance followed the Latvian fire code. A challenge arose from adjacent greenhouses that could not be relocated, requiring upgrades to the fire resistance class of new buildings. Issues with fire retardant coatings in high-humidity environments were noted, along with fungal risk if coating layers trap moisture.

The building envelope was designed using a two-stage principle: a ventilated air gap backed by waterproofing and protected by cladding. Insulation was strategically placed on the cold side of internal walls. A monitoring system (over 100 wireless sensors from Aranet) was installed to track temperature gradients and evaluate thermal performance over time. Moisture sensors were added using equipment from Scantronic.

4. Conclusions

This case study highlights the technical and practical viability of using mass timber for cold storage applications. It demonstrates how design, research, and construction can converge to innovate within both natural and industrial contexts. The building at Latvijas Finieris' Zābaki birch sapling nursery functions not only as a working facility but also as a long-term research station and educational model for future timber-based developments.

WOODEN ARCHITECTURE HERITAGE AND ENERGY-EFFICIENT RETROFITTING WITH WOOD-BASED SOLUTIONS

Indrė Užuotaitė

Artūrs Lapiņš

Lauri Tuulberg



Indrė Užuotaitė

Indrė Užuotaitė graduated from Vilnius University with a degree in cultural history and anthropology and cultural heritage protection. She holds a PhD in Art History from the Vilnius Academy of Arts and teaches future restorers. As a museum researcher, she contributed to the creation of the Museum of Urban Wooden Architecture in Vilnius. She is currently the Head of the museum.

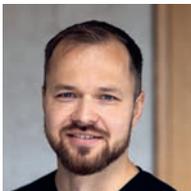


Artūrs Lapiņš

Restoration architect Arturs Lapins started his creative activity in 1994. Master of Architecture (RTU, 1996), Doctor of Arts (LMA, 2022).

During his creative activity he has researched, developed projects and supervised reconstruction and restoration of historical buildings of various scales for tenement houses, hotels, museums, office buildings, mansions, sacred buildings, design, landscaping and interpretation of historical sites, among them development and conservation solutions for ruins.

He has deepened his knowledge in international conservation courses, presented and published in conferences and publications on architectural history in Latvia and abroad. Member of the Latvian Association of Architects, Latvian Chamber of Crafts, Latvian Regional Academy of Architecture, ICOMOS. Winner of the Building Industry Grand Prize "Architect of the Year" (2019), Officer of the Order of the Three Stars (2023).



Lauri Tuulberg

Lauri Tuulberg is the CEO of Welement, a company specializing in timber-based prefabrication for both renovation and new builds. He holds MSc degrees in Industrial and Civil Engineering, and has worked as a site engineer and project manager on large-scale construction projects. Today, he focuses on advancing industrialised construction methods that improve quality, efficiency, and scalability across the building sector. His current interest lies in applying industrial logic and sustainable practices to modern construction challenges.

Reusing Architecture – the Future of Wooden Heritage in Vilnius

Indrė Užuotaitė

Head of the Museum of Urban Wooden Architecture (Department of Vilnius City Museum), Lithuania

Summary

Sustainability, which is constantly emphasised in contemporary lifestyles and new architecture, can also be achieved through the reuse of historic buildings and their elements. Efforts to preserve Vilnius' wooden architectural heritage began 20 years ago. The guidelines and measures established at that time for the conservation of the buildings are still in place today. The study focuses on two cases: the establishment of a museum in a historic wooden house at 52 Polocko Street in Vilnius and the possibilities and measures for the preservation of Šnipiškės, a wooden suburb of Vilnius.

Keywords: Timber constructions; Build heritage; Wooden architecture; Historic house; Preservation; Community inclusion; Historic suburb

Reusing wooden architecture

Wooden architecture is characteristic of Lithuania and the whole North-Eastern European region. You could say it is part of our identity. However, historic wooden architecture in cities is not being properly preserved – wood is retreating from the historic suburbs. In response to these trends, a strategy for the protection of wooden architecture in Vilnius was prepared in 2004, which identified areas of wooden houses and established a list of valuable wooden buildings in Vilnius. Two years later, in 2006, a programme for the preservation of wooden architecture was prepared. It outlined three ways of preserving historic wooden architecture: in situ, ex situ, and information preservation.

The first example is the adaptation of a historic wooden house for a museum of wooden urban architecture. Built at the end of the 19th century, the house was adapted for residential use, but in 2022, it became a museum. As a result of the sensitive restoration and the museum's activities, the restoration project and the sensitive adaptation of the building for a new use in 2023 have received three awards: the National Architecture Award (NAA), the Heritage DNA, and the European Heritage/Europa Nostra Awards.



Figure 1. Museum of Urban Wooden Architecture, photo by Norbert Tukaj, 2025.

The above-mentioned documents identify three means of heritage protection: regulation, promotion, and persuasion. They are revealed through the example of Šnipiškės, a historic suburb of Vilnius. Although Šnipiškės has long been a protected area, its boundaries were revised and significantly extended in 2024. Vilnius City Municipality, which initiated the changes, has also developed a programme to compensate homeowners for restoration costs. The Museum of Urban Wooden Architecture, in order to contribute to positive changes in Šnipiškės, has started to create a wood restoration workshop and a shared space for the museum and local community, which should be operational in a few years. These developments, along with various soft power initiatives, are helping to empower and organise an engaged community.



Figure 2. 3D visualisations of wooden houses in Kintų g. 10 (left) and Giedraičių g. 24, by AFTER PARTY, ŠA Atelier, VIETOS, 2025.

Conclusions

We have different tools and ways of preserving our wooden heritage. They cannot work alone, therefore an integrated approach is needed. A key element is the involvement of different communities, from specialists to heritage users and owners.

The Second Life of Wood Constructions

Arturs Lapins, PhD

Architect, Arhitektoniskas izpetes grupa SIA, Latvia

Summary

Latvia's rich wooden architectural heritage reflects its cultural identity and connection with nature. Preservation requires careful restoration to maintain historical value and aesthetics. Successful projects include Riga's renovated wooden houses and Jurmala's villas. However, wooden structures are vulnerable to damage without proper protection. The restoration approach not only preserves cultural heritage but also promotes sustainable development, utilising wood as an ecological material. This research uses case studies from 30 years of practical restoration, emphasising transparency, diagnostic assessment, and traditional craftsmanship. The results highlight the importance of preserving historical authenticity and promoting hands-on skills.

Keywords: Historic wood architecture; Timber structures; Repair in situ; Traditional craftsmanship; Massive wood structures

1. Introduction

Latvia is rich in wooden architectural traditions, reflecting our cultural heritage and close connection with natural resources. Thanks to the past availability of the material, wooden structures are an integral part of the architectural identity of Latvia. The preservation and renovation of these buildings requires a careful approach that allows them to gain a second life, preserving both their historical value and aesthetic appeal.

There are several successful wooden architecture restoration projects in Latvia. Besides well-known examples of the collection of renovated wooden houses in Ķīpsala, buildings of Kalnciema Quarter and villas in Jūrmala, wooden heritage is an essential part of the building stock of Latvia. Riga historical centre, which is mostly known for its Art Nouveau architecture, comprises almost 800 buildings with wood load-bearing exterior walls, both log construction and timber frame structures. Wooden beams carry the ceilings of all above-ground floors in all masonry buildings. The same material is used for their roof structures, not to mention wooden doors, windows, staircases, etc. Even masonry churches such as Riga Dome, St. Jacob's Cathedral and others contain a substantial amount of wooden beams and columns, which make their roofs withstand winds and precipitation and raise their spires high in the sky.

However, wooden structures, if not protected, are subject to damage by moisture, pests and environmental influences, which makes them vulnerable. Their preservation requires not only technical solutions but also respect for historical authenticity.

2. Methods

The research is based on extensive use of case studies – practical recovery of the wooden buildings and their elements, designed and supervised by the author and his colleagues during the past 30 years. Restoration of wooden constructions is based on several important principles, defined by the internationally acclaimed documents.

The process begins with a thorough diagnostics – assessment of the building's condition, which helps to identify damaged areas and determine the necessary work. Architectural and historic research is carried out to understand the cultural and historical context of the building. Based on the acquired knowledge, the most appropriate restoration solutions are chosen. The practical restoration stage involves experienced craftsmen who use traditional methods and tools.

The repair of wooden elements consists of several subsequent stages. The process begins with eliminating the damaged parts, whether they are rotten, damaged by insects or show evidence of any other faults. Next, the remaining sound end of the wooden element is shaped for the replacement to be installed. Depending on the role of the element in the building, different joints can be applied. Preparation of the joint and working of the new element with the old requires state-of-the-art craftsmanship. For the load-bearing structures, scarf and splice carpentry joints are usually applied.

3. Results and discussion

Restoration is definitely a low-tech approach, which, contrary to mass production, requires patience, skills and hands-on experience. Highlighting these aspects must be part of the education process, leading to the young generation of craftsmen.

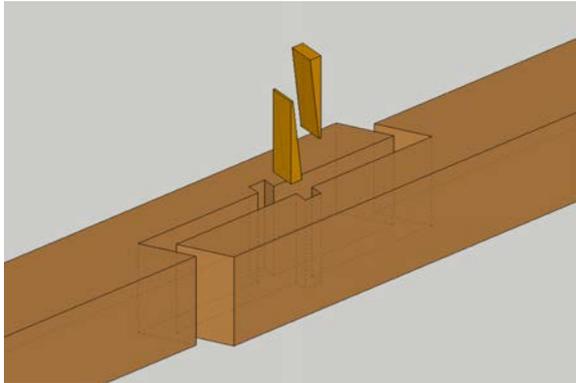


Figure 1. Riga Dome. Proposal for the split joint, to reinstall the dismantled diagonal stud (left). Assembling test of the scarf joint elements, Riga Dome, middle nave roof (right).

4. Conclusions

The second life of wooden constructions in Latvia is a story of respect for history and the skill of applying traditional methods to prolong the life of old structures. Restoration allows unique buildings to continue to exist as symbols of cultural heritage for future generations, while creating an aesthetically attractive and sustainable environment for our society.

5. Acknowledgements

The author pays credit to all the clients, with whom the passion and responsibility for the reconstruction of wood structures has been shared, as well as commilitones – structural engineers and craftsmen, who have spent their time and invested their time and skills to prolong the life of the essential, but vulnerable part of our built heritage.

From Prefab to Prefab

Lauri Tuulberg

Welement AS, Estonia

Summary

The presentation explores systemic challenges in scaling up the renovation of post-war mass housing in Europe. It argues that industrialised, prefabricated approaches offer a viable solution, but the real obstacle lies in outdated, fragmented processes and decision-making systems. A systems-level redesign is needed to achieve the speed and quality required for environmental and urban goals.

Keywords: Prefabrication; Mass housing; Renovation process; Energy performance; System design

1. Introduction

The European Union's climate neutrality targets have brought building renovation to the centre of environmental policy. However, across member states, the renovation of post-war apartment blocks – many of which were industrially produced – is advancing too slowly to meet emissions and energy targets.

This paper argues that to meet the scale of the challenge, renovation must itself become an industrialised, standardised process. Rather than treating each building as a unique case, we must treat the housing stock as a repeatable product class and manage it accordingly.

2. Methods

The observations and arguments presented are grounded in practical experience leading prefabricated timber renovation projects in Estonia and Germany. These projects have involved both design and construction phases, often working directly with housing associations navigating funding schemes, permitting, and resident engagement.

Insights are drawn from direct collaboration with stakeholders across the value chain. A systems-thinking lens is applied to identify recurring failure points in the renovation process, including fragmented decision-making, slow permitting, unpredictable funding cycles, and a general lack of architectural and spatial ambition.

3. Results and discussion

The current renovation process is primarily carried out through a decentralised approach, where individual housing associations are responsible for navigating technical planning, financing, permitting, and construction. This approach is ill-suited to the scale and urgency of the climate and energy goals.

The paper introduces the idea that the original buildings themselves were products – built using repeatable systems. Therefore, the most logical path forward is to apply prefabrication not only technically, but also systemically.

Additionally, new thinking around rooftop extensions and vertical additions is introduced as a way to help finance renovations while simultaneously increasing density within existing infrastructure footprints – offering a sustainable alternative to urban sprawl.

4. Conclusions

The key message is not simply that renovation must improve in quality, but that the **entire process must be reimagined**. Current systems of delivery are not fit for purpose when measured against environmental and social ambitions.

To reach real scale, the renovation process must be

- standardised across building types,
- centrally supported and pre-approved for funding,
- attractive to capital markets through pooled, low-risk packaging,
- designed with urban quality and user experience in mind.

This is not a technical gap. It is a system design failure – and it can be solved.

5. Acknowledgements

The author thanks the Forum Wood Building Baltic organisers for the opportunity to contribute to the dialogue on sustainable urban transformation in the region.

**EDUCATING
FOR WOOD:
PRACTICES IN
ARCHITECTURE,
STRUCTURAL DESIGN AND
CONSTRUCTION TRAINING**

Juliette Bekkering



Juliette Bekkering

Prof. Ir. Juliette Bekkering is a Full Professor of Architectural Design and Engineering at Eindhoven University of Technology (TU/e) and Principal Architect at Juliette Bekkering Architects. She also collaborates with Neutelings Riedijk Architects. With a strong background in both academia and practice, she focuses on sustainable architecture, circularity, and emerging technologies. Her research bridges theory and real-world applications, fostering innovation in bio-based and climate-responsive design. As an internationally recognised expert, she has contributed to cutting-edge research on biophilic design, 3D printing, and circular building strategies, shaping the next generation of architects.

Decarbonising Architecture: Designing from Nature, with Nature and Recycling

Juliette Bekkering, Prof. Ir.

Architectural Design and Engineering, Eindhoven University of Technology, Netherlands, & Architect director at Juliette Bekkering Architects associated with Neutelings Riedijk Architects, Netherlands

Summary

The building industry is facing many challenges due to climate change, material depletion, energy transition and loss of biodiversity. To develop sustainable, forward-looking architectural designs that can address all these challenges, new toolboxes must be created to solve multiple problems in one go. A design methodology is proposed that takes a holistic approach and addresses multiple aspects simultaneously. Three key drivers have been explored, along with approaches to implement them in designs: build from nature, build with nature, and build and recycle. This article showcases examples from education projects, research projects and two case studies where biobased materials, integrating nature and re-use of buildings, are simultaneously applied in the design to decarbonise architecture.

Keywords: Wood architecture; Recycling in design; Decarbonise buildings; Biobased materials; Biophilic design; Re-use and transformation of buildings; Nature-based solutions

1. Introduction: A formwork for decarbonising architecture in three steps

The building industry is facing many challenges, due to climate change, energy transition, material depletion and loss of biodiversity. This has caused a significant change in our profession and requires rethinking and redefinition of the tools we have, as architects and the role we fulfil in the profession. New tools have to be developed, and aspects such as energy performance, carbon footprint and life cycle analysis of materials have to be integrated in the development of the design of buildings. Can we design buildings as climate machines, with cutting-edge low-energy solutions? Can we introduce biophilic design and nature in buildings in order to increase well-being and biodiversity? Can we design with biobased materials to make zero-carbon buildings, and can we design in such a way that we build buildings that can be recycled, and their materials repurposed?

In every architectural proposal, multifaceted problems have to be addressed: proposing materialities, energy performance, user wishes, programmatic requirements and many more. To be able to do relevant proposals in architectural design, the complex nature of buildings requires addressing multiple targets to design sustainable and future-oriented buildings. Regulations, performance of materials, availability of materials, fire regulations, certificates or technical limitations currently prevent the upscaling of sustainable solutions. Therefore, this approach promotes not focusing solely on one solution, like designing with timber, but on a range of parallel solutions to decarbonise architecture and build with nature.

Research on architectural design often focuses on details and parts, components or specific technical fragments, or single solutions that cannot address the complexity and multifaceted reality of the architectural design of buildings as a whole, thus risking remaining in academic research that does not solve the complexity of problems the built environment is facing. To bridge the gap, a design methodology is developed with three key drivers in design: build with nature, build from nature, and build and recycle.

This design method is being developed in **education, research and practice**.

In education: Challenge students to design future-oriented buildings and teach them how to implement low-carbon solutions by integrating the above-mentioned three topics in their designs.

In research: Different subjects are being researched, like the development of 3D printing façade elements on double curved circular moulds to reduce waste and improve material use (NWO research with Prof. J. D. Bekkering and Assoc. Prof. Cristina Nan), the research into circularity in design by re-purposing existing housing stock and educational buildings and developing circularity in the Netherlands (PhD research by Emma Lubbers), by investigating the use of biobased materials, and exploring biophilic design, by designing with nature (PhD research on Biophilic Design and Integrating Nature in Architecture by Dr. Weijie Zhong).

And lastly, **in practice:** By implementing this design formwork in practice, the main goal is to decarbonise architecture.

This article explores these three faceted design methods in practice by showcasing two projects: one built project and one in development, designed by the author with Neutelings Riedijk Architects.

2. Methods

In the designs, different aspects are explored, such as developing novel technologies to reduce waste, reusing buildings and materials, building with biobased materials, as well as implementing biophilic design, which involves designing with nature to enhance biodiversity by integrating plants, animals and natural phenomena into buildings. These aspects lead to new expressions, new forms, and new identities.

In every design, we take three considerations:

How can we recycle?

How can nature be integrated into the design?

How can we design with a low carbon footprint and design with biobased materials?

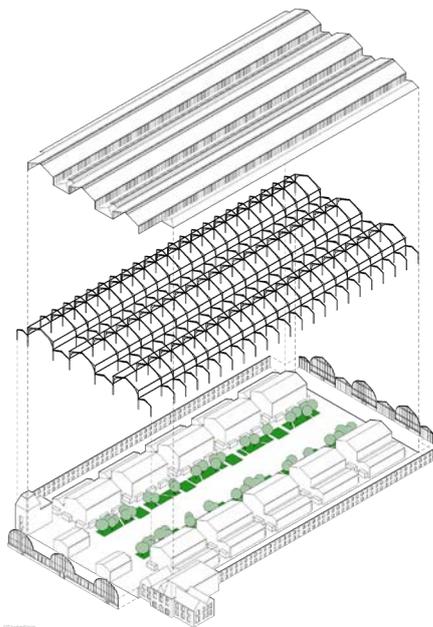


Figure 1. Exploded view of Gare Maritime, Neutelings Riedijk architects

Two projects will be highlighted: Gare Maritime in Brussels and Cité des Imaginaires (Jules Verne Museum) in Nantes. They are based on three key concepts.

Recycling and reuse: The iconic exterior of the buildings has been recycled, repurposed and refurbished. Any parts that cannot be reused are processed into new materials.

Building from nature: New additions and extensions to the building have been constructed using (as much as possible) bio-based materials.

Building with nature: Gardens, plants, water collection, wind and sun are integrated in the concept of the design

Gare Maritime is a refurbished freight station of 40 000m² along the quais of Brussels. The old building is completely carefully restored, preserving its iconic appearance in the city.



Figure 2. Interior view of the building. Photo by Filip Dujardin.

In Gare Maritime, 10 new pavilions with a total of 50 000 m² have been added with retail, public functions and offices. All the new additions have been made in timber: the 10 pavilions have been placed in the 140 m² x 280 m² freight station, made with CLT and finishings of oakwood. The lightweight wooden structure ensures a zero CO₂ footprint, quick assembly, precision and flexibility, both now and in the future, as the building can be dismantled. The building is the biggest CLT building in Europe.

A low-carbon and future-proof energy system is being integrated in the design with solar panels (17 000 m² of solar panels), water retention system, rainwater collection, geothermal energy and water storage, making the building a resilient 'climate-machine' with a BREEAM Excellent certificate.

Building with nature: A lush indoor garden with over 3 000 m² of plants and trees is integrated into the design, offering spaces for events, gatherings, and opportunities to connect with nature and promote wellbeing.

The Jules Verne Museum in Nantes is a recycled and repurposed old mill along the Loire river, and it will be transformed into a museum and culture centre, called: Cité des Imaginaires.

The building consists of a heritage Hennebique concrete structure that in big parts will be restored and repurposed. As the concrete structure is feeble, on top of the recycled and reused Hennebique concrete structure, a timber construction with the museum spaces is being proposed, that is light, easy to mount, low-carbon and flexible, now and in the future. The walls and infills are made of hempcrete and other bio-based materials, assuring it is a low-carbon building.

The building features a large indoor garden/orangery and a roof garden with rich vegetation to promote biodiversity and the well-being of users. Rainwater is collected for the grey water circuit and garden maintenance. Solar panels provide electricity, and the building is cooled using underground water basins and cold heat storage.

These different features enable the building to function like a machine, ensuring low-energy performance and comfort, thereby increasing its performance. The characteristic elements of the mill are also being preserved.

3. Results and discussion

A one-sided design strategy that only considers bio-based materials cannot always answer all the questions that a building design poses. The question we must ask ourselves is: Can spreading our ambitions and focusing on circularity, decarbonisation, and building with nature lead to buildings with better results? A diverse design strategy makes it possible to tackle various problems simultaneously in the design: **decarbonising architecture**. By also focusing on circularity and building with nature, an attempt is made to respond to issues such as increasing biodiversity, preserving iconic buildings, constructing buildings with materials that are not bio-based but are recycled, thereby leading to zero-carbon footprint buildings, and finally increasing social interaction and well-being.

4. Conclusions

In the face of urgent environmental challenges – ranging from climate change and biodiversity loss to material depletion and the energy transition – the architectural profession must radically rethink its methods and responsibilities. This paper has demonstrated that a one-sided approach is insufficient; instead, a holistic design methodology built around three interconnected principles – build from nature, build with nature, and build and recycle – offers a powerful pathway for decarbonising architecture, addressing the complexity of contemporary architectural demands.

The projects Gare Maritime and Jules Verne Museum exemplify how this approach can be translated into architectural solutions. Both projects showcase the power of combining material reuse, biobased innovation, and biophilic design to create buildings that are circular, low-carbon, nature-inclusive and socially enriching.

By adopting this multifaceted approach, architects can move beyond isolated problems to integrated solutions for decarbonising buildings. Such an approach not only lowers the environmental impact of our buildings but also contributes meaningfully to human well-being and ecological regeneration – charting a forward-looking path for the future of architecture.

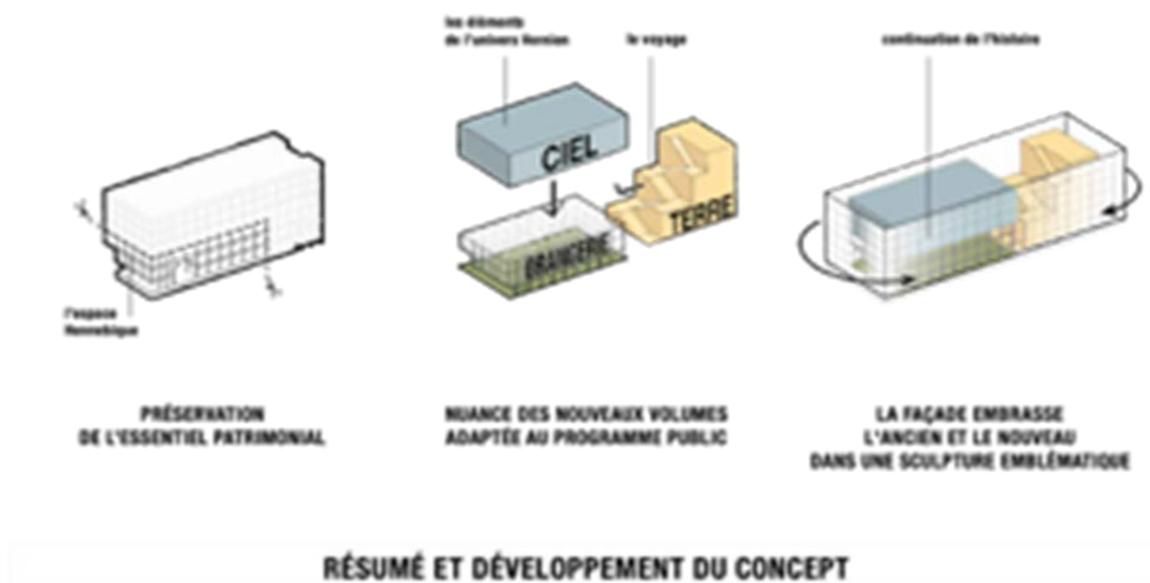
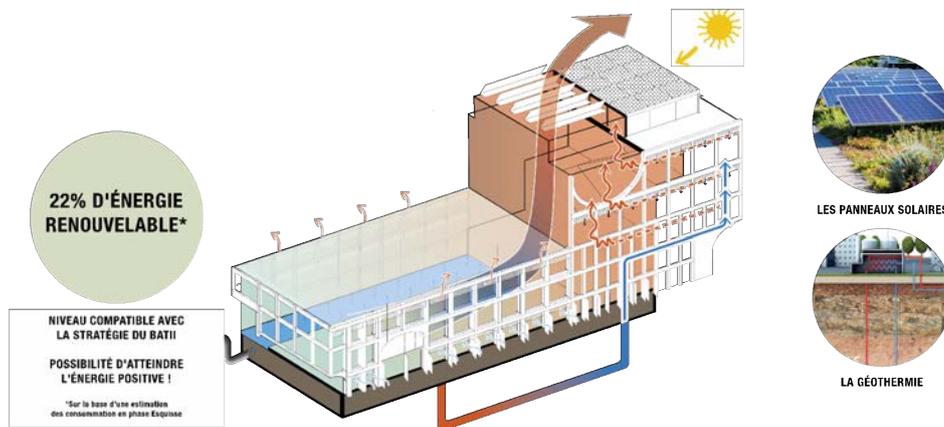


Figure 4. Concept diagrams of Cite des Imaginaires, Neutelings Riedijk architects.

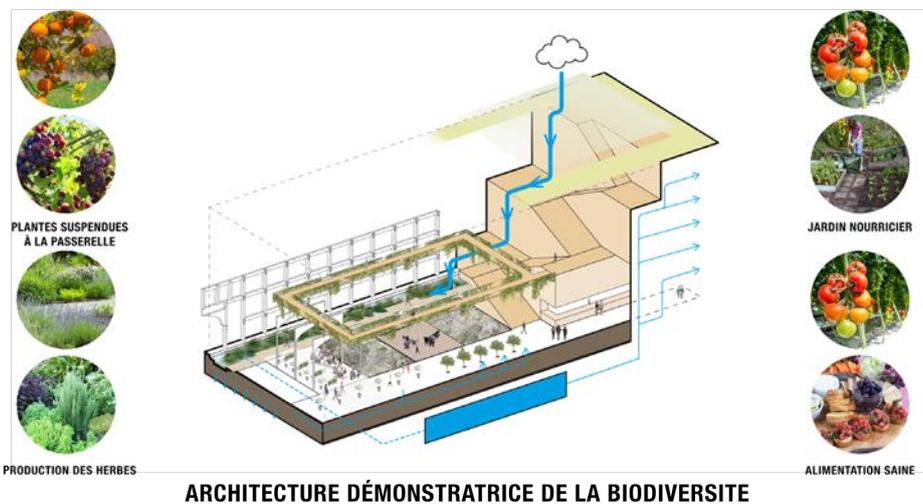


Figure 5. Interior rendering of the orangerie, Neutelings Riedijk architects.



REDUIRE L'IMPACT CARBONE : UTILISATION DES ENERGIES RENOUVELABLES

Figure 6. Concept diagrams of renewable energy in Cite des Imaginaires, Neutelings Riedijk architects.



ARCHITECTURE DÉMONSTRATRICE DE LA BIODIVERSITE

Figure 7. Concept diagrams of biodiversity in Cite des Imaginaires, Neutelings Riedijk architects.



Figure 8. Rendering exterior view of Cité des Imaginaires, Neutelings Riedijk architects.

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Cité des Imaginaires, Nantes: Neutelings Riedijk Architects (with Juliette Bekkering);
Client: Municipality of Nantes.

CONTINUATION OF THE FORUM – SCIENTIFIC ACHIEVEMENTS

Michiel Riedijk

Jørgen Tycho



Michiel Riedijk

Michiel Riedijk is a founding partner of Neutelings Riedijk Architects, a globally recognised firm specialising in public and cultural buildings. After obtaining his Master's in Architecture from TU Delft, he co-founded the practice in 1992, leading award-winning projects like the Antwerp MAS Museum and the Dutch Institute for Sound and Vision, that redefine urban transformation and innovative construction. His firm's pioneering sustainable work, including Gare Maritime, has inspired a new wave of timber-based, circular architecture. He is a former Professor of Public Buildings at TU.



Jørgen Tycho

Jørgen Tycho is a Norwegian architect with over 15 years of expertise in timber construction.

Formerly managing a CLT production, he now directs Oslotre, a design-build firm he founded in 2015.

Jørgen works with innovative biological architecture, integrating wooden solutions with prefabrication and high-tech methods.

Oslotre's pioneering work in timber architecture has earned them international acclaim for their award-winning timber architecture.

The Future of the Past – Decarbonisation, Circularity and Sustainability in Architectural Practice

Michiel Riedijk

Neutelings Riedijk Architects, Netherlands

Summary

This paper demonstrates how architectural quality, sustainability and circular thinking can go hand in hand, through the design of meaningful buildings that last. Using iconic examples such as Gare Maritime in Brussels, the new City Hall of Deventer, Rozet Cultural Centre, the ISALA Building and the Naturalis Biodiversity Centre in Leiden, the paper illustrates how adaptive reuse, timber construction, and nature-based solutions are applied in ambitious public projects. The focus is on creating buildings with a strong identity and beauty that foster ecological and social value in the public realm. Central themes include long-term design thinking, biodiversity integration, and a collaborative design process rooted in context and heritage. As the Anthropocene unfolds, the built environment must radically shift towards climate-conscious architecture. Neutelings Riedijk Architects shows how this future can be grounded in the best traditions of the past.

Keywords: Wood architecture; Adaptive reuse; Heritage architecture; Sustainable transformation; Timber construction; Urban renewal; Public buildings; Structures and materials.

1. Introduction. We design thoughtfully today, for the long-lasting icons of tomorrow

1.1. Low-impact and nature-based, identity and beauty, collaborative design process

At **Neutelings Riedijk Architects**, we design buildings that are expressive, functional and rooted in the public domain. With great attention to context, structure and experience, we strive to create sustainable architecture that contributes to a more meaningful, collective and liveable future. Our projects range from museums and public buildings to housing and hybrid typologies, often in complex urban settings. Across all scales, we combine powerful conceptual clarity with a love for material, detail and craftsmanship..

Low-impact and nature-based

We integrate nature-based strategies into all our projects to reduce the environmental impact of buildings and to strengthen urban ecosystems. Vegetation, water, and natural materials are applied in ways that go beyond aesthetics – they play an active role in improving air quality, stimulating biodiversity, and regulating temperature. Whether in dense city centres or more open settings, these green systems become spatial drivers for public life and ecological awareness. Our ambition is to build not only for people, but also for nature.

Identity and beauty

We aim to design powerful buildings that engage their surroundings with clarity and confidence. Through sculptural form, rhythm and rich materiality, we create architecture with a strong public presence and lasting beauty. Every project seeks to express the cultural and functional meaning of its program, while contributing to the identity of the city. We believe that memorable architecture adds value through emotion, character, and narrative.

Collaborative design process

Architecture is a collective effort. We work closely with our clients, consultants and end-users in a process based on dialogue, trust and curiosity. We analyse the complexities of site and program and respond with designs that are rigorous yet imaginative. This collaborative approach allows us to deliver buildings that are not only intelligent and efficient but also meaningful and generous.

2. Methods

2.1. Naturalis Biodiversity Centre

Strategy and methodology

The Naturalis Biodiversity Centre was strategically designed to seamlessly merge its existing and new structures into a singular, iconic landmark, combining a museum, laboratory, offices, and archives into a unified institution for biodiversity research and public engagement. The extensive renovation and new construction project, completed between December 2016 and May 2019, encompasses approximately **38 000 m² of gross floor area**, comprising 19 000 m² of renovation in the older sections and 17 000 m² of new construction. The existing 62-meter-high depot tower, which has been a city landmark since 1999, was retained. The architectural design by Neutelings Riedijk Architecten focused on spatial sequence, tectonic rhythm, and material expressiveness to celebrate nature's logic and diversity. The new exhibition building is distinctively shaped as **four staggered parts**, presenting both constructive challenges and opportunities. A central, expansive atrium serves as the connecting element between the old and new parts of the institution, allowing the public, scientists, and staff to navigate their respective routes upon entry. The atrium, which widens from bottom to top, creates a grand space. Its 'crown facade' is a monumental three-dimensional concrete structure, a lacework of interlocking oval, triangular, and hexagonal shapes that filter daylight, enhancing the hall's grandeur and monumentality.

Sustainability and performance

The building is designed for long life, adaptability, and low environmental impact. It incorporates numerous sustainable features, including the **reuse of existing structures and components**. Extensive use of **FSC-certified wood products**, concrete with recycled aggregates, and C2C-certified linoleum, carpet, gypsum, and masonry interior walls demonstrates a commitment to sustainable material use. **Green roofs** contribute to biodiversity and water buffering. Energy efficiency is a key aspect, with heating primarily generated by electric heat pumps and supplemented by a city district heating connection. A **thermal energy storage (WKO) system** provides 68 % of the cooling demand (resulting in 81 % energy savings) and 35 % of the heating demand (20 % energy savings). Climate control in the depots is meticulously regulated for temperature, relative humidity, and air purity to preserve the vast collection of over 42 million objects. The building utilises demand-controlled ventilation in exhibition halls, restaurants, and offices, adjusting to occupancy levels. Energy-efficient LED lighting is used throughout, with office lighting automatically adjusting to daylight levels. Additionally, **240 solar panels** on the roof contribute to the building's electricity needs.

Well-being and circularity

The monumental atrium floods the building with daylight, connecting all parts of the program visually and socially. Within the atrium, a spiralling **trappenberg (staircase mountain)** encourages exploration, designed as a monumental ascent with 3-meter-wide stairs and landings. This staircase is crafted from concrete walls rising from the ground floor, clad with red travertine from Iran, and interspersed with white concrete relief elements designed

by fashion designer Iris van Herpen. These relief patterns, inspired by fossils and natural forms, were developed using advanced parametric design and virtual reality visualisation for precise detailing. Logistical routes are clearly separated; museum visitors have distinct entrances and paths, while back-of-house operations, including a **“quarantine zone” for potentially contaminated collection materials**, have their own secure, non-crossing routes. Visitors move intuitively, and staff enjoy open workspaces with visual access to nature. Materials such as natural stone, oak, and concrete provide tactile and robust finishes throughout.

Result and impact

Since its opening in 2019, Naturalis Biodiversity Centre has emerged as a significant cultural and scientific landmark in the Netherlands. It now attracts over **40 000 visitors annually**, doubling its previous visitor numbers. The institution houses one of the world’s leading biodiversity collections, comprising **over 42 million objects**, positioning it among the top five globally. This includes the immense *T. rex* Trix, acquired in 2016, which has a permanent honorary place in the Dinotijd (Dino Time) hall. Its expressive design and public visibility have transformed scientific research into an engaging civic experience, establishing Naturalis as a pioneering hybrid institution – at once a museum, workplace, laboratory, and community hub. The realisation of this unique building required immense dedication from all involved, and in 2021, Naturalis was recognised as the **European Museum of the Year**.

2.2. Stadhuiskwartier Deventer

Strategy and methodology

The Stadhuiskwartier in Deventer was strategically conceived to revitalise the civic heart of the city by seamlessly integrating a contemporary extension into its rich historic fabric. The project merges six monumental buildings, including the 17th-century Old Raadhuis, the 1662 Wanhuis, the 18th-century Burgemeestershuis, the 1637 Landhuis, and the 19th-century de Hereeniging, with a new volume, forming a cohesive spatial ensemble that respects the medieval city grid while establishing a new public identity. The extensive renovation and new construction project, with construction starting in December 2013 and opening in April 2016, encompasses a total of **24 000 m² of gross floor area**, comprising 20 000 m² of new construction and 4000 m² of renovation, restoration, and sustainability upgrades to existing national monuments. The new addition reinterprets traditional Dutch step-gables with modern craftsmanship, giving the city a recognisable silhouette and a transparent, accessible town hall. The design for the Stadhuiskwartier aligns with Deventer’s typical urban structure of gardens and inner courtyards connected by paths, alleys, passages, and gates. The complex is organised around two newly designed courtyards: an open courtyard around the former mayor’s house, known as the Burgemeestershof, and a covered inner courtyard, the central hall, where residents, visitors, and municipal employees can meet. Additionally, two green city gardens are located on the sides of the Polstraat and Assenstraat buildings, connecting to the adjacent residential areas. A new continuous public route runs on the ground floor from the Grote Kerkhof, through the Burgemeestershof and the central hall, to the Burseplein and then to the Brink. A second public route, perpendicular to the first, connects the city centre to the alleys leading to the IJssel river. The new front building on the Grote Kerkhof features two storeys with a roof and a facade composition with strong vertical lines, mirroring the adjacent historic buildings and naturally integrating into its historical surroundings. The facades of the Stadhuiskwartier feature alternating closed brick sections and open filigree wooden elements, with large-format masonry and relief window frames, using multiple brick tones for a vibrant colour palette. The filigree facades consist of an oak framework of varying dimensions, which incorporates an integrated art installation by artist Loes ten Anscher, featuring 2264 unique aluminium-cast fingerprints of Deventer residents, creating a large public artwork that makes the Stadhuiskwartier the ‘House of Citizens’.

Sustainability and performance

The Stadhuiskwartier Deventer is recognised as one of the most sustainable government buildings in the Netherlands. This is attributed to a smart design that incorporates high spaces with abundant natural light and air, extensive use of natural resources, the integration of greenery within the building, and the application of various technical sustainable measures. The numerous windows, skylights, and high ceilings generously admit daylight, creating a pleasant working environment while simultaneously reducing electricity consumption. The exposed concrete throughout the building contributes to a high-quality, comfortable indoor climate by buffering heat or cold across different seasons, and includes concrete core activation for temperature regulation. The shed roof construction in the public hall prevents direct sunlight, thus avoiding excessively high temperatures within the building. Fresh air is introduced into the building via ventilation ducts and grilles in the windows and floors, and warmed air is efficiently removed via the atrium, reusing residual heat. The utilisation of sunlight, rainwater, and water from the IJssel river for both cooling and heating purposes makes the Stadhuiskwartier over **25 % more energy efficient** than comparable buildings in the Netherlands. The project achieved a **GPR score of 8 to 9** and received the **BREEAM Excellent certification**. Specifically, the BREEAM-NL New Construction Design Phase 2011 v1.0 certificate was issued on 5 March 2013, and the BREEAM-NL New Construction Completion Phase 2011 v1.0 certificate was issued on 22 July 2016, with a total score of 75.38 %. Key subscores included 86.67 % for management, 81.25 % for health, and 88.89 % for water. More than 80 % of the wood used during the construction was **FSC-certified sustainable wood**, and the old city hall and Landshuis were sustainably renovated to achieve an **energy label A/B**.

Well-being and circularity

The design prioritises well-being through an emphasis on daylighting and natural ventilation, with employees working in offices arranged around an open central atrium. Visitors are welcomed via a clear and accessible routing, with distinct public counters. Materials selected underscore durability and character; robust and solid materials like anthracite natural stone flooring guide visitors through the public areas, including the central hall and Burgemeestershof. Walls, stairs, columns, and cassette ceilings are made of concrete, finished with solid oak frames and infills. Meanwhile, the oak filigree facade, incorporating aluminium fingerprints, extends from the exterior into the interior around the courtyard and central hall, blurring the line between indoor and outdoor public spaces. Private spaces, primarily offices and back offices, also utilise concrete and solid oak combined with soft white and grey interior tones and furnishings. The project embodies a long-life, loose-fit design ethos through flexible interior layouts and the careful integration of old and new construction. The ground floor provides public access, but different areas can be separately opened or closed for specific events, such as the annual Deventer book market or the 'Deventer op Stelten' festival, enhancing flexibility and security. The internal circulation for staff is primarily located on the first floor, ensuring distinct and secure routes separate from public access, solving security and access control issues for both old and new sections. The new basement houses internal goods logistics, including for the company restaurant, and connects seamlessly with the old, historic basement circuit. The urban design incorporates a system of courtyards and squares that connect to Deventer's typical urban structure. The Burgemeestershof features a reflective pond that mirrors the facades, with water spouting from gargoyles in a wide seating bench. This courtyard, adorned with shrubs, fig trees, and shade-loving plants, has a fresh, green aesthetic, and wisteria adds an intimate, Mediterranean touch along the wooden arcades, making it a popular setting for weddings. Furthermore, the project embraces **nature-inclusive building** practices, aiming to maintain and strengthen biodiversity within the urban environment. This includes the creation of habitats for local ambassador species like the house sparrow, swift, wall plants, and bats. The two new city gardens, for instance, are comprised of 90 % edible plants, including wild tulips, strawberry plants, herbs, cherry, apple, and pear trees, attracting bees and butterflies and serving as food sources. Green roofs on the main building also contribute to biodiversity and water management, absorbing moisture and regulating temperature.

Result and impact

Completed in April 2016, the Stadhuiskwartier is now a **civic icon for Deventer**, demonstrating how historical continuity and contemporary architecture can seamlessly merge into a unified whole. It serves as a prime example of sustainable renovation, adaptive reuse, and dignified public architecture. The project has brought renewed vitality to a previously deserted part of the city centre. The restoration of historical alleys, which now form part of the publicly accessible routes, has significantly improved social safety in the area. The Stadhuiskwartier has received recognition for its architectural excellence, including the **Dutch Architecture Prize**. The building's success and its innovative approach to integrating heritage with modern sustainability and public access position it as a model for future municipal regeneration projects.

2.3. Culture Centre Rozet

Strategy and methodology

Rozet, located at Kortestraat 16, Arnhem, was conceived as a vibrant cultural hub to revitalise the city's heart. Opened in 2013, it houses diverse educational and cultural institutions, including the Public Library, Folk University, Heritage Centre, Art Company, and horeca. This **11 900 m² gross floor area (BVO)** project was designed to seamlessly bridge Arnhem's historical and post-war urban fabric, acting as an anchor point and catalyst for urban development along the central route between the Station area and Kerkplein. The design's core is the 'inner street' or 'Kennisberg' (Knowledge Mountain), a glazed public gallery that ascends from Bartokplein to the roof, connecting all functions and users. This public gallery integrates various functions like exhibition areas, foyers, auditoriums, and study spaces, fostering interaction and exploration. The semi-transparent facade, composed of sand-coloured, vertical pre-fabricated concrete elements with reliefs and symbolic rosettes, visually communicates internal activities and provides fixed sun protection while allowing deep daylight penetration through high windows.

Sustainability and performance

Rozet is lauded as one of Arnhem's most sustainable buildings, with sustainability being an integral part of its design methodology for over two decades. It achieved an **EPC value of 0.60** and a **GreenCalc+ score of 205**, indicating a sustainability performance **22 % above Building Decree requirements**. The inner street operates as an energy-neutral ventilation system, leveraging natural draft. Efficient energy generation is provided by a **heat/cold storage (WKO) system** and mechanical air handling with heat recovery and CO₂-controlled ventilation. Passive ventilation contributes to a **40 % lower energy load** and a stable indoor climate without active cooling. The building boasts a highly insulated thermal envelope ($R_c \geq 4.0 \text{ m}^2\text{K/W}$ for external partitions) with HR++ glazing (U-value max 1.2 W/m²K) and improved air and water tightness. Deep window reveals help shield from solar radiation, reducing the need for active cooling. A **1100 m² moss-sedum green roof** contributes to cooling, water buffering, and biodiversity, and enhances the efficiency of the **125 integrated solar panels**. Furthermore, over 80 % of the wood used is **FSC-certified**.

Well-being and circularity

Prioritising user well-being and operational efficiency, Rozet's design focuses on bringing people together in an attractive and inspiring atmosphere. The **inner street serves as the heart of the user experience**, creating an **open, bright, and dynamic environment** that invites interaction and exploration, with **60 % of all spaces directly connected to it to stimulate encounters**. This design fosters an inspiring and pleasant environment for staying, studying, and working.

Abundant natural daylight is a key feature, ensured by large facade openings and high vertical windows that allow light to penetrate deep into the building. The inner street

functions as a **natural ventilation shaft**, promoting thermal draft for fresh air circulation and helping maintain a **stable indoor climate between 21–24 °C without active cooling**. **CO₂-controlled ventilation systems** further ensure optimal air quality and prevent unnecessary ventilation. **Acoustic optimisation** was a priority in the design, achieved through sound-absorbing materials and 'box-in-box' constructions for sensitive spaces like music studios and auditoriums. The building is designed as a **low-threshold, accessible facility for all, including wheelchair users**, featuring a ground-level entrance and multiple elevators. Intuitive wayfinding within the building reduces the need for signage by 20 %. The use of high-quality finishes and natural materials like stone, concrete, and oak contributes to a positive sensory experience and overall user well-being. An intensive **participatory design process**, involving user workshops, ensured the building aligned closely with the diverse needs of its occupants.

Regarding **circularity**, Rozet was designed with a **total cost of ownership (TCO) approach**, aiming to limit and control construction and long-term operational costs. The **compact building form** minimises wasted traffic space and reduces energy loss. The selection of **robust and high-quality materials**, such as recycled cobblestones and prefabricated concrete elements, contributes to a **30 % reduction in maintenance costs**. The project extensively utilised **FSC-certified wood**. Critically, the **flexible column structure and floor loading** were specifically designed to allow for easy reconfiguration and **future changes in function**, ensuring long-term utility and economic resilience. In fact, **80 % of the spaces are flexibly usable for multiple purposes**. A **1100 m² moss-sedum green roof** plays a role in circularity by contributing to cooling, water buffering, and urban biodiversity. Furthermore, a building management system continuously monitors installation performance, supporting efficient maintenance and a long lifespan. The inner street itself also acts as an economic driver due to its rentable and multifunctional spaces.

Result and impact

Completed in 2013, Rozet has cemented its place as a significant cultural landmark in Arnhem, showcasing a successful integration of architecture, functionality, and sustainability. The project has garnered numerous prestigious awards, including the **Dutch Building of the Year 2015 (Expert Prize)**, **Best New Library of the Netherlands in 2014**, and the **Heuvelink Award 2014**. It also received nominations for the RIBA International Award 2016 and the Mies van der Rohe Award 2015. Its widespread public appeal is demonstrated by welcoming **30 000 visitors within its first six months**, with an average visitor stay 30 % longer than at traditional cultural institutions. The success is attributed to a collaborative and integrated design process between architects, interior designers, and the municipality, ensuring the project met its ambitious goals within budget and schedule. Rozet serves as an inspirational model for bringing diverse cultural and educational functions under one roof, fostering synergy and creating a dynamic, community-embedded public space.

2.4. Isala Building, Brussels

Strategy and methodology

The ISALA building project, located at Rue de la Loi 33, Handelsstraat 93-113, and Nijverheidsstraat 48-52 in Brussels, represents an **ambitious transformation** of an existing office building, formerly the Total HQ, into a sustainable, mixed-use landmark within the European Quarter. Designed by Neutelings Riedijk Architects and Jaspers-Eyers Architects, with conception dating back to 2020, the methodology for this 34 197 m² total gross floor area (BVO) project focuses on **deep environmental regeneration and circular design**. This involves retaining as much as possible of the original 1950s stone facade and structure, while also implementing 'urban mining' to reuse materials like raised access floors and surplus elements both in situ and from other projects. A central new green courtyard, functioning as a full-ground garden, is designed to flood the interior with natural daylight, creating biophilic workspaces and significantly boosting local biodiversity within the dense urban fabric.

Sustainability and performance

Isala aims for the **highest standards in sustainability**, aspiring to achieve **BREEAM Outstanding**, WELL Platinum, and DGNB Outstanding certifications. This is pursued through a comprehensive integration of renewable systems and passive design principles. The building design adheres to passive construction principles, featuring highly insulated facades, triple glazing, and a compact form to minimise energy demands for heating and cooling. The project is designed to be **CO₂-neutral and energy-positive**, completely eliminating the use of fossil fuels. Energy needs are met by renewable sources, including a geothermal system and solar panels, with some photovoltaic panels directly integrated into the facade of the upper floors. Innovative energy management technologies include high-efficiency heat pumps, a thermally activated buffer tank for heat and cold storage, and an advanced Whitebox MPC control system that optimises energy efficiency based on weather, occupancy, and building inertia. Furthermore, new additions are largely constructed from cross-laminated timber (CLT), a renewable material with a low carbon footprint that actively stores CO₂, contributing to a nearly zero operational carbon footprint. Water conservation is prioritised through rainwater and greywater recovery, green roofs, retention roofs, and underground buffering, allowing the site to fully process even a T100 rainstorm.

Well-being and circularity

Health, comfort, and soft mobility are fundamental aspects of Isala's design. The building promotes well-being through abundant natural daylight, achieved by enlarging office floor plates to an optimal 20-meter depth and incorporating first and second daylight zones. A healthy indoor climate is ensured by an optimal mix of mechanical and natural ventilation, with CO₂-controlled systems. Biophilic design elements, such as visible wood structures and extensive interior and exterior green spaces, like the inner garden and winter garden, are integrated to foster connection with nature. To encourage active and healthy routines, the project prioritises soft mobility with ample bike storage (241 total spaces, including for electric and cargo bikes) and improved accessibility for persons with reduced mobility on all levels. The building's inherent flexibility and adaptability, allowing easy reconfiguration or conversion of office spaces to residential or hotel functions, ensure its long-term relevance. Circularity is deeply embedded through material reuse and LCA-led workshops, further supported by advanced water management systems for extreme rainfall events.

Result and impact

Upon its anticipated completion between 2025 and 2027, Isala will stand as a flagship of sustainable renovation in Brussels, transforming an existing building into a dynamic, open, and resilient hub that meets 21st-century demands. The project encompasses approximately 30 500 m² of office space, 3150 m² of residential space, 500 m² of retail space, and a 770 m² courtyard. This exemplary transformation, integrating a mixed-use program including 20 apartments and commercial spaces at the ground level, is designed to be open and vibrant. It will support social inclusion and enhance local retail vitality by activating the ground floor with public functions and creating pedestrian passages that connect surrounding streets to the inner garden. By fostering a positive impact on the urban environment and the European Quarter's identity, Isala demonstrates how obsolete buildings can be redeveloped into high-value social and ecological assets, thriving long after traditional office hours.

2.5. Gare Maritime, Brussels

Strategy and methodology

Gare Maritime, located at the Tour & Taxis site in Brussels, is a remarkable transformation of what was once Europe's largest freight station, dating back to the early twentieth century. The project's core concept, designed by Neutelings Riedijk Architects, is 'a city

where it never rains'. This involved transforming the vast space under seven interconnected monumental station roofs into a vibrant, mixed-use urban district comprising offices, retail, hospitality, a food market, and public event spaces. Twelve new wooden pavilions, totalling 45 000 m² of new construction, were strategically placed under the existing side aisles. This creates an internal network of boulevards, streets, parks, and squares, mirroring a real city. The project was realised through a highly effective **bouwteam (building team) collaboration**, involving the client (Extensa/Nextensa), architects, engineers, contractors, and specialists, fostering open communication and synergy.

Sustainability and performance

Gare Maritime stands as a state-of-the-art example of sustainable design, being **fully energy-neutral and fossil-free**. It has achieved a **BREEAM Outstanding certification**, with an impressive score of 88.7 %. The project extensively utilises **cross-laminated timber (CLT)** for the new pavilions, making it the **largest CLT project in Europe**. This choice of wood significantly reduces CO₂ emissions (by 3500 tons) and shortens construction time due to prefabrication and dry construction methods. Energy generation relies on **17 000 m² of solar panels** on the roofs and integrated solar cells in the Picardstraat glass facades. An innovative **geothermal system** extracts water from a deep rocky layer, a first for Brussels, reducing CO₂ emissions by approximately 500 tons annually compared to conventional systems. Rainwater is collected and reused for toilet flushing, garden irrigation, and adiabatic cooling, further minimising environmental impact.

Well-being and functionality

The design of Gare Maritime deeply prioritises user well-being and operational functionality, creating an attractive and inspiring environment. The entire space under the station roofs is now **publicly accessible**. The grand central space maintains a pleasant climate year-round, following the seasons, suitable for a wide range of public and business events. This climate is naturally ventilated and supported by approximately **100 tall trees in ten themed indoor gardens**. Brussels' artist Henri Jacobs designed eight distinct mosaics for the squares, enhancing wayfinding and providing a unique identity to the public spaces. The pavilions are designed for **flexibility and adaptability**, allowing easy reconfiguration for diverse functions like offices, retail, and hospitality. The new structures are entirely detachable and independent of the historical frame, accommodating thermal expansion and facilitating future reuse. An iterative and participatory design process, involving various user groups, ensured the design met diverse needs and allowed for adjustments even during construction.

Result and impact

Completed in 2020, with phased delivery from November 2019 to October 2021, Gare Maritime has become a significant cultural and economic landmark. It has received numerous prestigious awards, including the **MIPIM Special Jury Award 2021**, the **ARC20 Architecture Award**, the **Belgian Building Award**, and the **Europa Nostra Heritage Award**, and was a shortlisted finalist for the EU Mies van der Rohe Award and Dezeen Awards. The project serves as an inspiring mixed-use space for both young and established companies. It significantly contributes to the **sustainable development of the Tour & Taxis site** and the broader Canal Zone in Brussels. By making the central space and flanking gardens publicly accessible, Gare Maritime seamlessly integrates into the surrounding urban fabric and adjacent park, enhancing the area's permeability and establishing a continuous public route. Its success as a tourist attraction, hosting diverse events from concerts and exhibitions to markets and sports tournaments, underscores its role as a vibrant new hub for Brussels.

3. Results and Discussion

The architectural projects of Gare Maritime, Deventer City Hall, Rozet Cultural Centre, ISALA Building, and Naturalis Biodiversity Centre collectively demonstrate a profound commitment to decarbonization, circularity, and sustainability, while simultaneously creating spaces of strong identity, beauty, and social value. These projects illustrate how a forward-looking architectural practice can be deeply rooted in the traditions of the past, offering models for a climate-conscious built environment.

Low-impact and nature-based solutions

A central theme across all projects is the reduction of environmental impact through innovative design and material choices. **Gare Maritime** stands out as fully energy-neutral and fossil-free, achieving a BREEAM Outstanding certification. Its new pavilions are Europe's largest Cross Laminated Timber (CLT) project, significantly reducing CO₂ emissions by 3500 tons and shortening construction time. Similarly, the **ISALA Building** targets CO₂-neutrality and energy-positivity, aiming for BREEAM Outstanding and WELL Platinum certifications, utilising highly efficient heat pumps, geothermal energy, and integrated solar panels, some directly in the facade. It also incorporates 'urban mining' to reuse materials from other sites. **Deventer City Hall** is recognised as one of the most sustainable government buildings in the Netherlands, with a BREEAM Excellent rating, employing geothermal heating/cooling, solar panels, and a compact structure with natural ventilation and concrete thermal mass for climate regulation. **Rozet Cultural Centre** features an energy-neutral inner street acting as a natural ventilation shaft and boasts a 1100 m² moss-sedum roof with solar panels, leading to a 40 % lower energy load than legally required. **Naturalis Biodiversity Centre** integrates green roofs for biodiversity and water buffering and utilises sustainable materials like concrete with recycled granulate and FSC-certified wood. These examples collectively showcase a shift towards minimising energy consumption and material waste, often through passive design strategies and renewable energy sources.

Identity and beauty

Beyond technical performance, each project prioritises creating a unique identity and enhancing aesthetic appeal. **Gare Maritime** transforms a vast historical structure into 'a city where it never rains' complete with boulevards, streets, squares, and ten themed indoor gardens with 100 tall trees, enhanced by Henri Jacobs' mosaics. The visible CLT-wood interior contributes to a pleasant ambience. In **Deventer City Hall**, an art integration project involved casting 2264 unique fingerprints of citizens into aluminium facade elements, making the building literally the 'House of the Citizens'. **Rozet** uses its semi-transparent facade and 'inner street' to visually connect internal activities with the city, adorned with sand-coloured concrete elements featuring symbolic rosettes. **Naturalis** features a stunning central atrium with a 3D concrete structure resembling interlocking molecules, filtering light through circular windows, and exhibition halls clad in natural stone with friezes designed by Iris van Herpen. These artistic and design choices create strong visual identities and foster a sense of place.

Collaborative design process

The success of these complex transformations relies heavily on integrated and collaborative design approaches. For **Gare Maritime**, a highly effective bouwteam collaboration involving the client, architects, engineers, and specialists fostered open communication and synergy, particularly crucial for the then-unfamiliar CLT construction. The **ISALA Building** involved iterative processes for optimal design and the integration of multiple disciplines. **Rozet** emphasised a holistic approach with intensive user workshops to ensure the design aligned with diverse occupant needs, leveraging the expertise of an integrated design team. **Naturalis** similarly benefited from a multi-disciplinary team, with Neutelings Riedijk Architects leading the integration of architectural, structural, and technical aspects,

involving users through thematic sessions. This collaborative methodology, often supported by BIM, ensures that ambitious sustainability and design goals are met, fostering buildings that are not only high-performing but also deeply embedded in their context and responsive to user needs.

These projects collectively demonstrate that architectural quality, sustainability, and circular thinking are not mutually exclusive but can be harmoniously integrated through thoughtful design, innovative material use, and strong collaborative processes, creating resilient and meaningful structures for the future.

4. Conclusions

The examined architectural projects – Gare Maritime, Deventer City Hall, Rozet Cultural Centre, ISALA Building, and Naturalis Biodiversity Centre – serve as compelling testaments to the successful integration of decarbonisation, circularity, and sustainability within contemporary architectural practice. These diverse public buildings collectively highlight key observations that inform a climate-conscious future for the built environment.

Firstly, a pervasive commitment to **decarbonisation and energy efficiency** is evident. Projects consistently achieve or aim for high sustainability certifications such as BREEAM Outstanding/Excellent and WELL Platinum. This is realised through strategic choices like implementing **energy-neutral or energy-positive concepts**, utilising **geothermal energy**, extensive integration of **solar panels** on roofs and even facades, and employing advanced passive design principles such as optimal insulation, triple glazing, compact building forms, and natural ventilation systems. The **cross-laminated timber (CLT)** construction in Gare Maritime, Europe's largest CLT project, significantly reduces CO₂ emissions by 3500 tons and shortens construction time. Rozet's energy-neutral inner street functions as a natural ventilation shaft, contributing to a 40 % lower energy load than legally required.

Secondly, these projects underscore the paramount importance of **circularity and long-term adaptability**. Adaptive reuse is a cornerstone, minimising demolition and maximising the retention of existing structures and materials. Concepts like 'urban mining' as seen in the ISALA Building, demonstrate the integration of materials recovered from other construction sites. The deliberate choice of robust, high-quality materials, including recycled cobblestones and prefabricated concrete elements in Rozet, leads to substantial reductions in maintenance costs (e.g., 30 % for Rozet) and extends building lifespan. Furthermore, designing for **flexible reconfigurability** is crucial, as exemplified by Rozet's column structure and floor loading, allowing for future function changes, with 80 % of its spaces being flexibly usable.

Thirdly, the focus on **identity, beauty, and human well-being** goes hand-in-hand with sustainability. Spaces are designed to be attractive and inspiring, fostering human interaction through elements like Rozet's inner street, which encourages encounters by connecting 60 % of all spaces directly to it. Abundant daylight, acoustic optimisation, and the use of natural materials contribute to a pleasant and healthy indoor climate. Accessibility for all users, including wheelchair users, is a fundamental design principle. The unique artistic integrations, such as Henri Jacobs' mosaics at Gare Maritime and Iris van Herpen's friezes at Naturalis, imbue buildings with strong identities and ecological/social value.

Finally, the success of these ambitious projects is intrinsically linked to **collaborative and iterative design processes**. Multi-disciplinary teams (bouwteams) involving clients, architects, engineers, and specialists fostered open communication and synergy from concept to completion. Intensive participatory processes, including user workshops, ensured designs were closely aligned with the diverse needs and desires of occupants, leading to optimal functional outcomes and strong community buy-in.

Concrete advice for the construction field

For companies (developers, contractors, architects):

- **Prioritise a holistic and integrated approach.** From the earliest design phases, integrate all aspects of sustainability – social, urban, and technical – into your methodology. Form diverse bouwteams with clear communication channels to leverage collective expertise for complex sustainable projects.
- **Invest in circularity from the outset.** Adopt a total cost of ownership (TCO) mindset, focusing on robust materials and design for disassembly to minimise long-term maintenance and facilitate future reuse. Maximise adaptive reuse of existing structures and actively explore 'urban mining' for material sourcing.
- **Embrace low-carbon materials and renewable energy.** Integrate large-scale timber construction (e.g., CLT) where feasible to significantly reduce embodied carbon. Prioritise fossil-free and energy-positive designs using geothermal, solar, and advanced passive strategies.
- **Design for people and context.** Create spaces that actively promote user well-being and social interaction through ample daylight, natural ventilation, acoustic comfort, and intuitive wayfinding. Ensure designs are accessible to all users. Integrate nature-based solutions like green roofs and indoor gardens to enhance biodiversity and human connection to nature.
- **Foster participatory processes.** Engage future users and stakeholders in iterative design workshops to ensure the building truly meets their needs and creates a sense of ownership and belonging.

For researchers in the construction field:

- **Long-term performance and impact studies.** Conduct comprehensive post-occupancy evaluations and long-term monitoring of energy performance, material degradation, and user satisfaction in advanced sustainable buildings. This data is crucial for validating design assumptions and informing future innovations.
- **Advance circularity metrics and technologies.** Develop more sophisticated life cycle assessment (LCA) tools that fully account for the environmental and economic benefits of adaptive reuse and modular design. Research new techniques for material recovery, processing, and reintroduction into the construction supply chain at scale.
- **Quantify social and ecological co-benefits.** Further investigate the measurable impacts of human-centric and nature-inclusive design on occupant health, productivity, and social cohesion. Research the effectiveness of specific nature-based solutions (e.g., green roofs on biodiversity enhancement) in urban environments.
- **Refine collaborative design models.** Study the dynamics and success factors of integrated design teams and participatory processes, especially when working with innovative and complex sustainable goals. Identify best practices for fostering synergy and achieving consensus across diverse stakeholders.
- **Innovate timber and hybrid structures.** Continue research into advanced wood construction methods, particularly large-scale CLT applications, to optimise structural efficiency, fire resistance, and cost-effectiveness. Explore hybrid material systems that combine the benefits of timber with other sustainable materials.

5. Acknowledgements

The successful realisation of these ambitious architectural projects was made possible by the dedication, expertise, and collaborative spirit of numerous individuals and organisations. We extend our sincere gratitude to the following key contributors whose efforts were instrumental in achieving the outlined sustainability, circularity, and well-being goals.

Gare Maritime, Brussels

- Client/developer: Extensa (now Nextensa), whose visionary leadership and commitment enabled the transformation of Gare Maritime into a sustainable and mixed-use urban hub.
- Architectural design: Neutelings Riedijk Architecten (NRA) as the leading architects for the new build-in volumes and landscape architecture, coordinating the integral design from concept to completion.
- Co-architects: Bureau Bouwtechniek and Jan de Moffarts Architecten were also part of the architectural team.
- Structural engineering: Ney & Partners BXL for the renovation of the historic steel structure and new build-in volumes.
- MEP and building physics: Boydens Engineering and IFTech (geothermal installation).
- Landscape architecture: OMGEVING.
- Main contractor: MBG.
- Wood construction contractor: Züblin.
- Installation contractors: Cegelec, VMA, NTSA, Van Hoey, IFTech.
- Art integration: Brussels visual artist Henri Jacobs designed eight mosaics for the squares.
- Project management and BREEAM assessor: Bopro.

Deventer City Hall

- Client/developer: Gemeente Deventer.
- Architectural design: Neutelings Riedijk Architecten.
- Structural engineering: Aronsohn Constructies Raadgevende Ingenieurs.
- Installation consulting: Hiensch Engineering.
- Building physics consulting: DGMR Raadgevend Ingenieurs.
- Landscape architecture: Bosch Slabbers tuin en landschapsarchitecten.
- Main contractor: BAM Utiliteitsbouw Regio Noordoost.
- Art integration: Artist Loes ten Anscher designed the 2,264 unique fingerprints in aluminium for the facade.
- Cost consulting: Basalt Bouwadvies.
- Interior design: Neutelings Riedijk Architecten (fixed interior), Atelier PRO (loose interior), and OTH (council chamber).
- Certification: Dutch Green Building Council (BREEAM 'Excellent' certification) with Duurzaamheidscoach.nl as the Licensed Assessor.

Rozet Cultural Centre, Arnhem

- Client/developer: Gemeente Arnhem.
- Architectural design: Neutelings Riedijk Architecten. (Project Architect: Michiel Riedijk).
- MEP and building physics: Ingenieursburo Linssen, Van Losser Installatiegroep (W Installations), and E.T.I. Leerkes (E Installations). DGMR Raadgevende Ingenieurs was responsible for building physics, acoustics, and fire safety.
- Main contractor: Bouwbedrijf Wessels Rijssen bv.

- Art integration: Arnhem-based design agency Catalogtree collaborated on the facade's rosette design.
- Interior design: Neutelings Riedijk Architecten (general interior), and Merckx + Girod with DMDJS (office interior).

ISALA Building, Brussels

- Client/developer: INFINITO SA and Immobil.
- Architectural design: Neutelings Riedijk Architects and Jaspers-Eyers Architects (executing architect). (Dieter De Vos, Project Architect at Neutelings Riedijk).
- Structural engineering: Group D.
- MEP advisor: Boyden's part of SWECO.
- Sustainability consultant: SuReal.
- Circularity/urban mining advisor: NaturaMater.
- Landscape design: Erik Dhont Landscape.
- Certification: The project aims for BREEAM Outstanding, WELL Platinum, and DGNB certifications.

Naturalis Biodiversity Centre, Leiden

- Client/developer: Naturalis Biodiversity Center.
- Architectural design: Neutelings Riedijk Architecten led the integral design team. (Project Architect: Prof. Ir. M. Riedijk).
- Structural engineering: Aronsohn Constructies raadgevende ingenieurs bv.
- Installations: Huisman & Van Muijen (advisor), and Installatiecombinatie ULC – Kuijpers vof (contractor).
- Building physics/sustainability: DGMR (advisor).
- Main contractor: J. P. van Eesteren TBI.
- Art integration: Dutch fashion designer Iris van Herpen designed the concrete reliefs, and Studio Tord Boontje created the graphics.
- Cost consulting: IGG / Bointon de Groot.
- Landscape architecture: H+N+S.
- Building design (Bouwkundig ontwerp): ABT BV Ingenieursbureau.
- Concrete producer: Hibex (facade and frieze concrete).

Hasletre – a Demountable and Reusable Timber Office Building in Oslo

Jørgen Tycho

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Summary

Hasletre is a 3000-square-meter demountable and reusable timber office building in Oslo, designed for sustainability and the circular economy. Completed in 2022, it is Norway's first of its kind, featuring prefabricated timber elements and innovative timber-to-timber connections. The project reduces greenhouse gas emissions by 60 %, and 80 % reduction of steel use, compared to concrete and steel building systems and is BREEAM NOR Excellent certified. The interior focuses on reuse, with 60 % of furniture repurposed. Designed for flexibility, it accommodates future modifications. Hasletre showcases sustainable architecture, contributing to environmental goals while serving as a model for circular construction in the industry.

Keywords: Timber architecture; ReuseReduceRecycle; Biological architecture; Healthy interior.

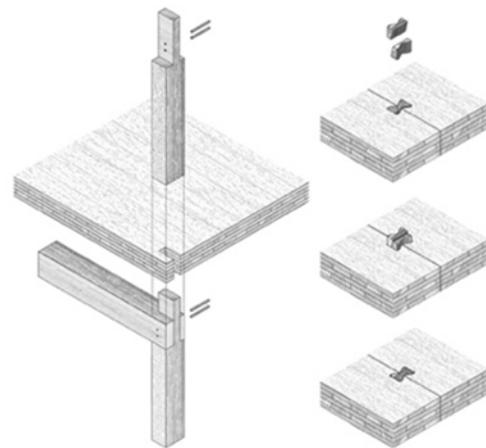


Project Overview

Located in northeast Oslo, HasleTre is a 3000-square-meter office building with four wooden floors and a basement made of CO₂-reduced concrete. As Norway's first dismantlable and reusable wooden office building, it sets a new standard for the circular economy in construction, emphasising timber-to-timber connections for easy disassembly and reuse. Built in just nine months – six months above ground – the building was completed in fall 2022 and is leased long-term to Save the Children. It prioritises sustainability, incorporating salvaged furniture and materials.

Design Process

The design of HasleTre was inspired by a study by OsloTre, which showed that substituting wood for steel and concrete could reduce greenhouse gas emissions by 60 %. The process involved collaboration among architects, developers, and consultants to establish ambitious environmental goals. The project adhered to circular economy principles, aiming for BREEAM NOR Excellent certification. Prototypes for timber-to-timber connections were tested early to ensure disassembly feasibility.



Building Concept

HasleTre's structure is optimised for disassembly, using timber connections that minimise steel and maximise reuse potential. The building features cross-laminated timber (CLT) panels and innovative connectors, allowing for flexible assembly and future reuse. Its modular interior, with adjustable wooden floors, enhances adaptability and long-term sustainability.



Environmental Features

HasleTre reduces greenhouse gas emissions by 60 % over its 60-year lifecycle, in line with Norway's 'FutureBuilt Zero v02' guidelines. Locally sourced timber and BREEAM NOR Excellent certification underscore its environmental commitment. The office furniture used by Save the Children was predominantly second-hand, saving over 35 tons of CO₂. Natural materials such as wood and wool in the interior regulate humidity, creating a healthy and comfortable working environment.



Circular Economy and Impact

Circularity is key to HasleTre's design, with an emphasis on reuse and recycling at the building's end of life. Office furniture was refurbished, and wool byproducts were used in acoustic partition walls. The building supports biodiversity with green facades, biotope roofs, and rainwater basins, and promotes sustainable transport with easy access to bike networks and public transit.



Conclusions

HasleTre is a model of sustainable architecture, demonstrating how circular economy principles can revolutionise construction. The building's innovative design prioritises adaptability, reuse, and environmental responsibility, setting a benchmark for future projects that strive for a more sustainable built environment.

FIRE SAFETY AND SERVICE LIFE OF TIMBER STRUCTURES

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Kārlis Livkišs

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Jānis Milzarājs is currently the CEO and Co-founder of SIA CASTOR CONSTRUCTION – a professional provider of Project Management, Construction, Design & Build and Real Estate Development services.

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Jānis Milzarājs has graduated from Riga Technical University and University of Latvia and holds a Diploma of Civil Engineer and a Master's degree in Social Sciences in Economics.

Jānis Milzarājs has a wide experience in Construction Design & Build projects, and CASTOR CONSTRUCTION Ltd has executed more than 50 Industrial and Commercial projects in the role of Main Contractor in Latvia.

The key Customers during the years of operation in Latvia have been JSC Latvijas Finieris, DHL Latvia Ltd, Lindstrom Latvia Ltd, JSC Air Baltic Corporation, Stockmann Latvia Ltd, etc.



Kārlis Livkišs

Karlis is a project manager and research consultant at the Danish Institute of Fire and Security Technology (DBI). His main professional interests include facade fire safety, fire testing and modelling. Karlis has received his PhD from Lund University (Sweden) for the work on project FIRETOOLS, done in cooperation with DBI. Karlis holds a Master's degree in Fire Safety Technology from program IMFSE (cooperation between Ghent University, Lund university and University of Edinburgh) and a Professional Bachelor's degree in Civil Engineering from Riga Technical University.



Mikko Salminen

Mikko Salminen (Structural Fire Engineering Lead for Europe at Jensen Hughes) holds a PhD in Structural Fire Engineering. He has over 15 years of experience in performance-based structural fire safety analysis of timber, steel and concrete structures to achieve optimal, fire-safe structural solutions ranging from detailed analysis to evaluation of entire structural systems.

The Insight into the Experience of Using Wooden Structures in Industrial Buildings in Latvia

Janis Milzarajs

Co-Founder and Board Member, CASTOR CONSTRUCTION Ltd.



Summary

The purpose of the study is an overview of the first steps of using wooden structures in industrial buildings in Latvia, and particularly in the construction of the factory VEREMS of JSC Latvijas Finieris, starting in the year 2005 and expansions in 2012 and 2025, covering 40 000 m². The study highlights the learning points of the erecting wooden structures over the past 20 years, particularly using beams and trusses in structures, as well as the values of the wooden structures.

Values

Twenty years ago, JSC Latvijas Finieris made a strategic decision to utilise wood products in the development of its production facilities, thus learning in practice several ecological, economic and social advantages provided by the wider use of wood products in everyday life.

As one of the leading companies in the forest industry in Northern Europe, Latvijas Finieris has undertaken the mission to (re-)establish traditions to develop industrial buildings by using wood products.



Figure 1. Factory VEREMS of JSC Latvijas Finieris construction in 3 stages in the years 2005, 2012 and 2025 – the first wood structures in industrial building.



Figure 2. Furniers factory of JSC Latvijas Finieris – warehouse construction in wooden structures in 2021. Main contractor CASTOR CONSTRUCTION Ltd. Design Remm Ltd.

Conclusions

The wooden structures in industrial and commercial buildings could be successfully applied and are highly recommended in Latvia. The wooden structures are competitive material compared to other structures in terms of sustainability and reduced environmental impact.

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Jensen Consult un Arhis Inženieri Ltd

8 A.M. Ltd

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Fire Performance of Wooden Facades

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¹ *Danish Institute of Fire and Security Technology, Denmark*

Summary

The BioFacades: UpHigh project investigated ventilated, non-fire-retardant-treated wood-clad facades exposed to fire conditions. Ten large-scale tests were performed, where steel horizontal projections (plume deflectors) were used as physical barriers for limiting the vertical flame spread. The results demonstrated that when properly designed, plume deflectors can effectively limit the upward fire spread on the cladding surface and ventilation cavity. However, cladded internal corners pose an increased fire safety vulnerability. Moreover, the use of plume deflectors did not mitigate risks related to lateral flame spread or the generation of burning debris.

Keywords: Facade; Wood cladding; Fire behaviour; Reaction to fire

1. Introduction

Non-fire-retardant treated cladding in general cannot reach the required reaction to fire classification for application on the facades of multistorey buildings, following the pre-accepted fire safety solutions in Denmark. Nevertheless, in Denmark, certified fire safety engineers are authorised to approve deviations from the pre-accepted solutions, provided it can be demonstrated that the proposed solution meets the functional requirements specified in the Danish Building Regulations. The presented study investigated the fire behaviour of ventilated, non-fire-retardant-treated wood-clad facades in large-scale tests. Large-scale tests were conducted, which allowed assessing the behaviour of a complete facade system exposed to fire impact, as opposed to smaller, material-scale testing done for EN 13501-1. The tests presented here mainly focused on the application of physical projections (referred to as plume deflectors) for limiting vertical fire spread on the facades.

2. Methods

The fire behaviour of ventilated facades, built with non-fire-retardant treated wood cladding and insulated external wall panels, was evaluated during 10 large-scale tests. The tests were primarily based on the European approach to assess the fire performance of facades (large-scale) method [1] (EU method). The test rig consisted of a corner configuration facade of three storeys (ground floor and two upper floors). At the ground floor, a combustion chamber with a 350 kg wood crib used as the fire source was located. The wood crib was ignited, and as the fire grew, the flames extended outside the combustion chamber and impinged on the facade. The wood crib burned for around 35 minutes, and the test duration was set to 60 minutes. Several deviations from the proposed method were introduced. In some tests, the size and position of the artificial window opening were modified, and the facade system was not extended onto the short side wall of the test rig, as prescribed by the standard method.

The facade constructions were instrumented with thermocouples for temperature measurements, plate thermometers and heat flux sensors for heat flux measurements. Around 80 measurement points were present in each test. In addition, the formation of falling/burning facade parts was noted based on the visual observations.

As expected, the wood cladding on the ground and the first floor ignited in all tests. The failure of vertical fire spread criteria was defined when the temperature rise of 500 °C was measured or if flames were observed on the second storey.

3. Results and conclusions

The tested constructions are presented in Figure 1. Out of 10 tests performed, in six tests the flames did not spread to the second storey of the facade. In five out of these six tests, the plume deflector extended at least 305 mm outside the cladding. In the one remaining test (Test 9), a 207 mm extension was sufficient to limit the vertical fire spread. Nevertheless, only in one of the tests was the cladding also applied on the short side wall, creating a cladded internal corner (Test 4). This test was done with a plume deflector extending 314 mm outside the cladding, horizontally oriented cladding with a 25 mm ventilation cavity and relatively large artificial window openings.

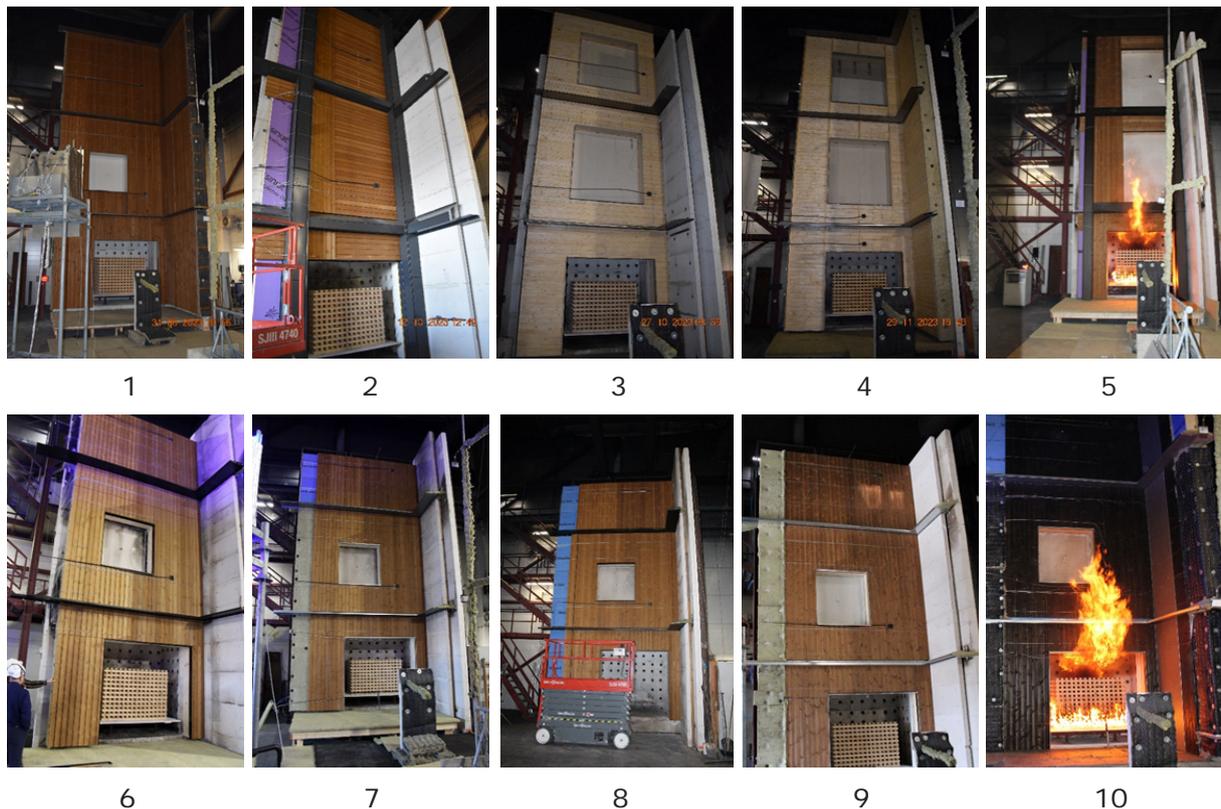


Figure 1. Ten constructions tested as part of the project BioFacades: UpHigh.

In Test 1, the vertical fire spread was observed already at the 11th minute of the test. It was therefore concluded that the cladded corner increased the upward fire spread risk due to extended flame lengths, created by the radiation heat feedback between the burning surfaces and air entrainment. The individual test reports and test videos are provided in reference [2].

4. Acknowledgements

The authors acknowledge Realdania for funding the project BioFacades: UpHigh and the project partners NRPE, CPH Village, Fælledby and Frøslev Træ.

References

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- [2] "BIOFACADES: UPHIGH." Accessed: Aug. 29, 2023. [Online]. Available: <https://brandogsikring.dk/en/research-and-development/development-of-fire-safe-bio-based-and-circular-construction-products/biofacadesuphigh/>

Structural Fire Engineering of Timber Structures in Natural Fires

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Summary

The fire resistance of timber structures has historically been assessed using testing and/or calculation methods based on principles such as charring rate and effective reduced cross-section. These methods typically only consider the heating phase of a standard fire. Recent experimental studies conducted by Jensen Hughes and Tampere University have shown that such calculation methods may be oversimplifying the assessments, especially during the cooling phase of a fire. Structural fire engineering (SFE), including advanced finite element methods (FEM) analyses, offers significant potential when analysing timber structures in more realistic fire scenarios than standard fire.

Keywords: Structural fire engineering; Timber structures; Fire tests; CLT; Numerical analysis

1. Introduction

The most typical (and relatively simple) approach to verify fire resistance of timber structures is to calculate the char depth in standard fire, determine the residual cross-section and check if it resists the fire situation design loads. Especially in large timber buildings, performance-based (PB) design is often a potential (or even required) option. The PB approach is usually based on actual fire loads, fire scenarios and design fires, which often differ significantly from standard fire, e.g., because the design (and real) fires always have a cooling phase.

The acceptance criterion in PB design of large buildings is often fire resistance for the whole duration of the fire. This criterion is challenging to verify for timber structures, as there is a limited number of methods available for fire scenarios other than standard fire. This study investigates the fire resistance of a typical timber structure (CLT-slab) in natural fire conditions experimentally and numerically to shed some more light on the abovementioned challenge.

2. Methods

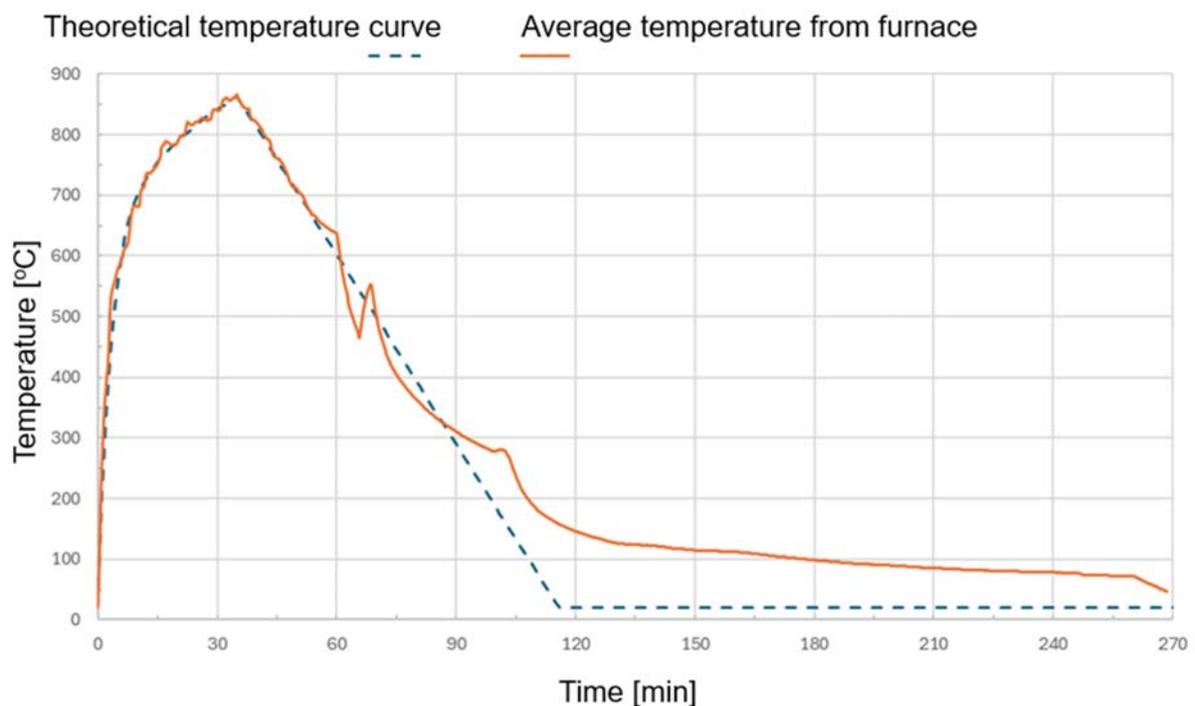
A loaded CLT-slab in natural fire was studied by Jensen Hughes (Tuomas Hakamäki's Master Thesis) and Tampere University Fire Laboratory.

2.1. Fire Tests

A fire test was conducted for a loaded 3.77 m long, 500 mm wide and 140 mm thick CLT-slab (lamellae 40-20-20-20-40). The loading (20.3 kN point load) was determined so that the slab would just achieve 60 minutes standard fire resistance (R 60) with the load. The fire exposure used in the test (34 minutes standard fire followed by a long cooling phase, see Figure 1) was determined so that, according to preliminary numerical analysis, the failure would occur clearly in the cooling phase of the fire.

2.2. Numerical Analysis

The CLT-slab described above was modelled thermally and structurally using SAFIR software (Gernay & Franssen, 2017). The main objective of the analysis was to investigate whether the numerical analysis can predict the failure of the slab conservatively during the cooling phase.



3. Results and discussion

The structural failure of the CLT-slab occurred at 4 h 23 min, which was approximately 3 h 49 min after the cooling phase started and over 3 h after the char depth had reached its maximum value. The maximum char depth of the slab was approximately 31 mm, and the deflection when the failure occurred was approximately 232 mm.

The failure predicted by numerical analysis occurred at 78 minutes, i.e. during the cooling phase, but clearly earlier than in the test. The maximum char depth was 30 mm, which was slightly lower than in the test (31 mm). The temperatures and deflections from tests and analysis are shown in Figure 2.

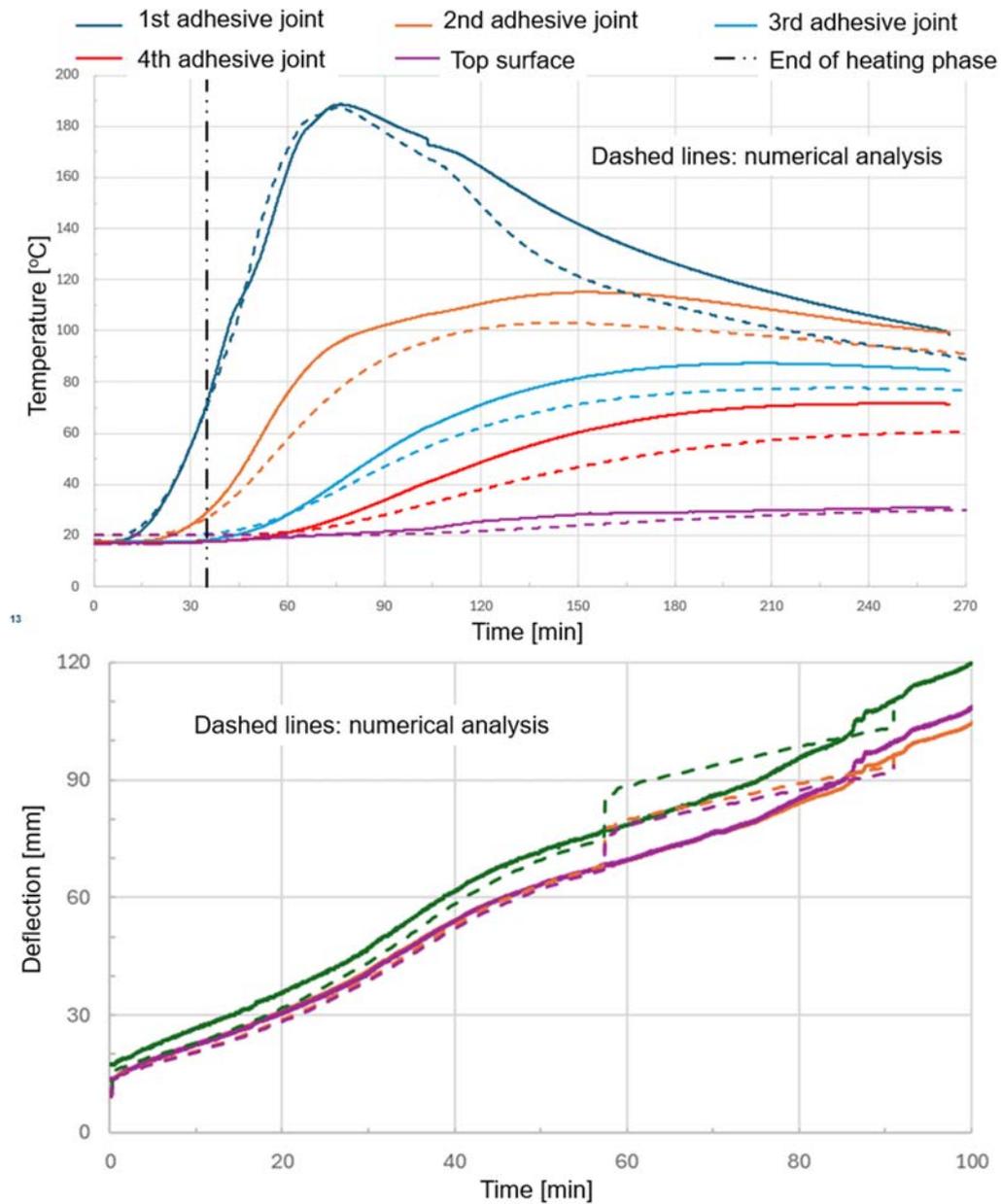


Figure 2. Measured and analysed temperatures (left). Measured and analysed deflections during the first 100 minutes (right).

4. Conclusions

The main conclusions of this work are as follows:

- The structural failure of the CLT-slab may occur late in the cooling phase of the fire.
- The timber cross-section may heat long after the char depth has reached its maximum value in natural fires, reducing the load-bearing capacity.
- Numerical analysis may be used to predict the failure in the cooling phase. However, the results seem to be very sensitive to different parameters, especially timber strength.

5. Acknowledgements

The competent work and advice of Tampere University Fire Laboratory, especially Professor Mikko Malaska and Doctoral Researcher Mika Alanen, are gratefully acknowledged.

RESEARCH ON WOODEN CONSTRUCTION

Targo Kalamees

Fredrik Westin

Elza Briuka



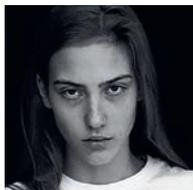
Targo Kalamees

Professor of Building Physics at Tallinn University of Technology. His research fields include the hygrothermal behaviour of building envelope structures, heat loss of building envelopes, hygrothermal loads, indoor climate and energy consumption of buildings, climate proofing and resilience, and future-proof buildings. He has led several research projects in the field of wooden buildings.



Fredrik Westin

Fredrik Westin is the Managing Director of the Swedish Wood Preserving Association and General Secretary of the Nordic Wood Preservation Council. He also serves as a board member of the European Wood Protection Association. With a strong background in promoting sustainable and durable wood use, Fredrik has been instrumental in advancing wood preservation practices across Europe. His work focuses on enhancing the service life and environmental sustainability of wood products, making them a preferred choice in construction and public infrastructure projects. Through his roles, he advocates for the safe and effective use of treated wood, emphasising its benefits in reducing carbon footprints and conserving resources.



Elza Briuka

PhD student at the Civil Engineering Institute of Riga Technical University. She obtained a Professional Bachelor's degree (2023) and a Professional Master's degree (2024) from Riga Technical University (RTU). Since the beginning of her career, she has worked in Latvian companies such as Ostby (ConPro) Ltd, JSC Pillar Capital, Būvkonsultants Ltd, and Skonto Prefab Ltd. Since 2024, she has been a research assistant at RTU Civil Engineering Institute and an engineer at CLTProfi Ltd, dealing with the design and research of wood and wood composite structures.

The Service Life of Modern Estonian Wooden Buildings

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Summary

This study examines modern wooden buildings in cold, humid climates, focusing on how material choice, design, and maintenance affect their durability and appearance. Inspections of 78 buildings, aged 8 to 20 years, revealed that design deficiencies were the major issue, impacting 57 % of buildings, particularly due to poor rainwater management. Maintenance problems affected 23 %, and material selection contributed 12 %. Transparent coatings and plywood facades were found unsuitable for Estonia's climate. User surveys showed that 81 % performed reactive maintenance, while 57 % lacked maintenance manuals. The study underscores the need for better design, material choices, and preventive maintenance, as well as clearer guidelines in national building regulations for sustainable management.

Key words: Wood architecture; Service life; Resilience; Climate proofing; Material selection; Design; Maintenance

1. Introduction

The service life of a building is influenced by several factors, including the durability of materials, design quality, construction execution, climatic conditions, usage, and maintenance practices. Typically, the design service life for load-bearing structures and envelope layers – such as thermal insulation, waterproofing, vapour and wind barriers, facade coverings, and roof coverings – is set at 50 years. However, modern architecture often incorporates global trends that may introduce design features suitable for warm climates, which can compromise the longevity of building envelopes in cold and humid environments. For instance, many contemporary wooden buildings in Estonia feature wooden facades that extend to the ground, lack eaves, and include concealed or complex rainwater systems, along with transparent coatings and wooden roofs. While these modern wooden structures aim to reduce carbon footprints and promote circular economy principles, their sustainability may be questionable if they cannot withstand the harsh environmental conditions typical of a cold and humid climate over their intended 50-year service life. This study aims to evaluate the condition of modern wooden buildings in such climates and identify the key factors that contribute to the deterioration of their exterior envelopes.

2. Methods

A total of 78 wooden buildings, aged 8 to 20 years, were studied, with the oldest from 2003. The research analysed exterior changes over time, focusing on facades, roofs, window frames, and coatings.

The changes in the exterior appearance of the buildings over time were visually assessed by comparing photos taken after construction with those taken during the site visit, along with on-site evaluations for possible damage. In addition to observing the buildings and assessing their exterior changes, feedback regarding the buildings' condition was gathered from owners and users. Future maintenance plans were also explored to evaluate proactive approaches to facade maintenance and to determine whether maintenance work is generally performed as needed or according to the maintenance plan provided with the project.

3. Results and conclusions

Based on this study, the following conclusions were drawn:

- Design deficiencies such as ineffective drainage, short eaves, and low plinth heights (Figure 1) primarily contribute to moisture-related damage in modern wooden buildings in cold, humid climates, accounting for 57 % of damage cases. Prioritising aesthetics over durability exacerbates these issues, leading to costly and environmentally burdensome maintenance.
- Outdoor-exposed glue-laminated timber elements and plywood facade panels proved to be more problematic than transparent-coated cladding facades.
- Reactive maintenance practices dominate, resulting in delayed repairs and increased life cycle costs. Notably, 23 % of damage cases are related to maintenance issues like coating flaking. Regular preventive maintenance, accompanied by clear instructions, is essential for enhancing durability and minimising costs.
- Materials such as transparent coatings and plywood are unsuitable for long-term facade use in cold, humid conditions due to their sensitivity to UV radiation. Proper material selection, including opaque coatings and sheltering glue-laminated timber, along with regular maintenance, can significantly enhance the service life of wooden facades.
- Uncoated wood and roofs are vulnerable to decay and often require replacement. Buildings should incorporate wide eaves and high plinths, avoiding exposed wood in cold, humid climates.
- Contradictions in building codes create ambiguity regarding maintenance responsibilities, highlighting the need for clear regulations to support comprehensive maintenance manuals.
- Life cycle assessment (LCA) and life cycle cost (LCC) calculations must realistically evaluate maintenance and replacement costs to inform clients about material selection and life cycle expenses.



Figure 1. Low-pitched wooden plank roof (<math><20^\circ</math>) (left) is replaced with a steel roof after <math><12</math> years of use (right). If the architecture has changed, should the title of Best Wooden House of the Year be taken away?

4. Acknowledgements

This work was supported by the Estonian Centre of Excellence in Energy Efficiency (grant TK230), the Estonian Research Council (grant PRG2732), and the ERA-NET Cofund Action 'ForestValue' project WoodLCC (N° 773324). The authors thank the Estonian Forest and Wood Industries Association (EMPL) for their collaboration and the homeowners and builders for sharing data.

NTR: Predictable Durability for Sustainable Wood Construction

Fredrik Westin

Managing Director, Nordic Wood Preservation Council, Sweden

Summary

This presentation introduces the NTR Wood Durability Quality System as a trusted framework for ensuring predictable biological durability and extended service life in treated and modified wood products. It outlines the system's purpose, structure, and use of European standardisation, with a focus on performance-based classification, product approvals, and third-party quality control. The presentation concludes that reliable durability certification is essential for advancing sustainable, low-carbon wood construction in Europe.

Keywords: Biological durability; Wood durability; Treated wood; Wood preservation; Wood modification; Service life; Use Class; Quality assurance; NTR



1. NTR Wood Durability Quality System

The **NTR Wood Durability Quality System** provides architects, engineers, specifiers, and policymakers with a reliable framework for choosing wood products with **proven performance and extended service life**. Developed and maintained by the **Nordic Wood Preservation Council (NWPC)**, it is a widely trusted quality system based on European standards, scientific evidence, and decades of field experience.

- **Trust and predictability:** NTR-certified wood is tested and classified for its resistance to biological degradation, providing end-users with clear expectations of service life in real conditions.
- **Defined protection classes:** From NTR A (in-ground) to NTR AB and NTR B (above-ground), as well as NTR B GL for glulam and 'NTR mod' classes for modified wood, the system covers a wide spectrum of treated and engineered wood applications.
- **Verified approvals:** Each treatment or modification technology undergoes a comprehensive assessment based on laboratory and field testing before being accepted into the NTR system and added to the NWPC Approval list.
- **Quality control:** Compliance with Internal Factory Production Control for wood treatment and continuous third-party audits of production sites ensure consistent compliance with NTR standards, giving professionals confidence that the wood will perform as labelled.

2. About NWPC and Nordiska Träskyddsrådet

The **Nordic Wood Preservation Council (NWPC)** – or Nordiska Träskyddsrådet – is the coordinating body behind the NTR system. It plays a critical role in uniting the Nordic wood preservation industry under a single quality and durability framework.

- **Established in the 1970s**, NWPC was created to harmonise national durability standards across Sweden, Finland, Norway, and Denmark.
- **Members are national wood preservation associations**, and it operates as a non-profit organisation focused on durability, sustainability, and market trust.
- **Manages approvals, classification rules, and assigning rights to accredited quality auditing**, ensuring that only approved products and verified production processes carry the NTR mark.

- **Publishes open, transparent technical standards**, helping specifiers and regulators choose appropriate and traceable wood products.

3. Biological durability and CEN standardisation

Biological durability refers to a wood product's ability to withstand decay caused by fungi, insects, and other organisms. The NTR system builds on established European standards to translate scientific durability classifications into practical, service life-oriented product specifications. Among others, these are the most prominent CEN standards in this respect:

- **EN 350:** Describes the natural durability and permeability (treatability) of wood species.
- **EN 335:** Defines Use Classes or 'exposure scenarios' for wood in various environmental exposures.
- **EN 599 and EN 113:** Standardised test methods for treated wood efficacy, forming part of the NTR approval process.
- **SS-EN ISO/IEC 17065:** External inspections in the NTR system are carried out by accredited bodies operating in accordance with this international standard for product certification systems, ensuring impartiality and high credibility.
- **CEN Standards from CEN/TC38** are used for assessing wood preservatives' efficacy against biological agents.

Together, these standards ensure that NTR-classified wood is not only durable in theory – it performs in practice.

4. Competitive, safe, and climate-smart

Treated wood, especially when sourced from **European forests**, provides an environmentally sound and resource-efficient alternative to tropical hardwoods and synthetic materials such as steel, plastic, or concrete.

- **Competitive material choice:** Treated Nordic and European wood offers **long-term durability at a lower environmental and financial cost** compared to imported hardwoods and non-renewable building materials.
- **Modern wood preservatives – tested and safe:** Today's preservatives are **scientifically evaluated under the EU's Biocidal Products Regulation (BPR)**. They undergo extensive risk assessments and may only be used when no unacceptable risks to humans or the environment are identified. This ensures **safe use in sensitive applications**, unlike older, now-restricted substances.
- **A tool for decarbonisation:** Durable wood extends carbon storage in buildings and reduces the frequency of material replacement. Substituting wood for more carbon-intensive materials directly supports EU climate goals and a circular economy.
- **Lower lifecycle emissions:** Studies confirm that treated wood's overall environmental impact – especially when durability is guaranteed – is significantly lower than alternatives in comparable applications.

5. Takeaway for customers, specifiers and policymakers

To build sustainably with wood, durability must be reliable and predictable. The NTR system offers a proven model for achieving that, combining science, regulation, and transparent industry practices into a quality label that professionals can trust.

Whether you are designing a low-carbon building, updating procurement criteria, or selecting materials for long-life outdoor structures, **NTR-classified wood is a practical and climate-smart choice.**

The Effectiveness Increase of Timber-Concrete Composite Slab

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² SIA CLTProfi, Latvia

Summary

The current version (first generation) of Eurocode 5 does not offer a standard calculation process for timber-concrete composite (TCC) elements.

This study addresses the enhancement of material efficiency and reduction in brittleness for timber-to-concrete adhesive connections for timber-concrete composite panels. Three groups of flexure-tested specimens were analysed as follows: six CLT panels (1400 mm × 400 mm × 50 mm) bonded to a 50 mm concrete layer, with two panels containing polypropylene microfibres and two panels incorporating polyethylene dowels for mechanical connection. Specimens were subjected to three-point bending tests and analysed using the transformed section method, γ -method, and finite element method with ANSYS 2023R2 software. Results indicated a 24.8–41.1 % increase for CLT panels strengthened with a concrete layer, and improved ductility and prevention of disintegration in timber-concrete composites with polypropylene microfibres.

Keywords: High-performance wood-based structures; Structures and materials; Load-carrying capacity; Timber-concrete adhesive connection; Ductility enhancement; Y-method; Three-point bending; Finite element analysis; Maximum vertical displacements; Stone chip method; Timber-concrete composite; CLT

1. Introduction

As the use of CLT and other timber structural materials in roofs and floors increases, so does the need to enhance their load-carrying capacity and performance. Combining timber with materials that have specific superior mechanical properties, such as concrete, can improve the load-carrying capacity of timber structures.

2. Methods

A simplified design method based on the transformed section method and the γ -method outlined in Annex B of EN 1995-1-1:2004 for mechanically jointed beams was considered for behaviour analysis of the beam-type timber-concrete composite panels. Also, linear FEM models were prepared using ANSYS software. The finite element models were developed to verify the results obtained by the simplified design method and the experiment. In the FEM software ANSYS, the SHELL element type was used for modelling the TCC specimens. Timber members and concrete layers were in the strength classes C24 and C20/25, respectively. Connections between all the layers of the FEM models were modelled as rigid ones. All the groups of laboratory specimens were loaded three times until the design value of their load-carrying capacities, and then loaded until collapse by the scheme of three-point bending.

3. Results and discussion

The collapse of the TCC specimens shows that adding microfibres to the concrete surface layer changes its behaviour under the failure load; the beam-type panels do not collapse brittle, and in some specimens, the concrete layer did not disintegrate at all but rather delaminated from the CLT section.

The actual load-carrying capacities observed during the experiment for all sub-groups of the laboratory specimens were higher than those evaluated by the simplified design method. The mean actual load-carrying capacities of sub-groups ASD, AS, and BS were equal to 77 kN, 91 kN, and 86 kN, which are 26.43 %, 49.43 %, and 41.22 % bigger than those evaluated by the simplified design method. It was stated that adding the concrete layer to the CLT panel increases the load-carrying capacity by 41 % compared to the plain CLT panel.

A significant difference between the modes of failure of the specimens of sub-groups AS and BS was observed (Figure 1). The mode of failure for the sub-group BS is characterised by the collapse of the CLT and concrete components. The disintegration of the specimens caused by the delamination of the concrete layer due to the collapse of the adhesive timber-to-concrete connection was also observed.



Figure 1. The failure mode of the laboratory specimens: (a) brittle TCC failure of BS type specimens, and (b) non-brittle failure with no disintegration of the TCC slab of AS type specimens.

4. Conclusions

It was stated that the addition of a concrete layer with a thickness of 50 mm and mechanical properties close to C25/30 strength class concrete results in a significant increase in the load-carrying capacity of the CLT beam-type panels with dimensions 1400 mm × 400 mm × 100 mm by 40.1 %.

The possibility of decreasing the brittleness of the adhesive timber-to-concrete connection by adding polypropylene microfibres was stated. Delamination of the concrete layer could also be prevented by using screws at an angle $<45^\circ$. It was shown that the addition of microfibres MAPEI PP-FIBER M6 to the concrete surface layer changes its behaviour under the failure load; the beam-type panels did not collapse brittle, and in some specimens, the concrete layer did not disintegrate at all but rather delaminate from the CLT section. It can be concluded that the addition of polypropylene microfibres increases the maximum vertical displacements of the specimens, causing a decrease in the modulus of elasticity of the concrete layer. The developed FEM model enables us to predict with the precision of 2.57 % the maximum vertical displacements of the specimens without adding the polypropylene microfibres.

5. Acknowledgements

This research is supported by Riga Technical University, Doctoral Academic Career Grant No. 1067, European Union Recovery and Resilience Facility-funded project No. 5.2.1.1.i.0/2/24/I/CFLA/003, and Latvian company SIA CLTProfi.

CLOSING SESSION OF THE FORUM

Sven Matt



Sven Matt

Sven Matts is a certified architect and court-sworn civil engineer, having graduated from the University of Innsbruck and Vienna University of Technology. From 2004 to 2012, he had a collaboration in Bernardo Bader Architects. In 2012, he founded an architectural office, Innauer Matt Architekten. From 2016 to 2019, he acted as a Member of the Board of the Vorarlberg Architecture Institute. Since 2018, he has been a member of the Design Advisory Board in the municipality of Alberschwende. Since 2020, he has been a visiting professor at the Technical University of Munich. Since 2023, he has been an active member of the Urban Planning Advisory Board of the city of Dornbirn.

Sense and Sensibility

Sven Matt

Innauer Matt Architekten, Austria

Summary

Sustainability in timber construction is still defined by the degree of usefulness and resource efficiency. In this strictly technical view, however, the aesthetic quality of timber construction is not considered. Durability and good design, that is sustainability in the true sense of the word and therein lies the strength of timber construction – it combines sense and sensibility.

Keywords: Wood architecture; Sustainability; Aesthetics in timber construction; Durability, Sense and sensibility

1. Introduction

Sustainability in timber construction is still defined by the degree of usefulness and resource efficiency. In this purely technical view, however, the aesthetic quality of timber construction is ignored. Even if architects should not use the term 'beauty' too loudly in their day-to-day work, it is still one of the key categories of sustainable construction. Beautiful buildings enrich their environment instead of just passively consuming it. Whether old or new, they create a profound bond with the place, the people and the landscape. They create identification and speak directly to the viewer. The usefulness, the utilisation, then seems self-evident.

2. Results and discussion

Wood as a material is characterised by its versatility, and beautiful timber constructions appear in the balance of their parts. The bold construction, which not only spans wide, but also does so with an impressive light-footedness. The finely textured timber facade, which, in addition to providing protection from wind and weather in richly coloured shades, also tells a story about its location and its contents. The naturalness, warmth and odour of untreated wood appeal to the emotions on many levels. The ability of wood to age gracefully also has a high aesthetic and, thus, emotional value. One obvious example of this is reclaimed wood, which is particularly popular in the Alpine tourism industry. Formerly extracted from old buildings by 'rural mining', the cosiness and homeliness can now also be quickly spaced onto walls and ceilings as a three-layer board without warping. From here onwards, the concept of beauty degenerates into simple banality. The loss of authenticity ends in a poor caricature of the original quality.

Good design requires a great deal of thought and development work, craftsmanship and therefore sufficient time – the added value comes from extra effort. In addition to the current shortage of materials and ongoing labour shortage, time is probably the most sought-after resource in our private and professional lives. But this is precisely where modern timber construction can flex its muscles. Hardly any other sector in the construction industry has integrated digitalisation, automation and prefabrication so successfully into the production process and yet has not lost its awareness of traditional craftsmanship. This opens up completely new possibilities for design. Added value no longer has to be created solely through additional work, thanks to the joinery robot and CNC machine.

3. Conclusions

The 'soft' qualities that an object or material radiates guarantee its longevity. While functions and uses can change within just a few years, a beautiful building, an aesthetic material or a finely designed object can last for a long time without any problems. The loveless, throwaway piece of furniture has long since been reincarnated as wood chips, while the solid wood plank – on which it once stood – has aged gracefully and still flatters the feet. Durability and longevity, that is, sustainability in the true sense of the word and therein lies the strength of wood – it combines sense and sensuality.



Figure 1. Kriechere 70, Entrance, Innauer Matt Architekten, Bezau, Austria (left). Kunstraum Kassel, Courtyard View, Innauer Matt Architekten, Kassel, Germany (right).

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Latvian wood construction cluster

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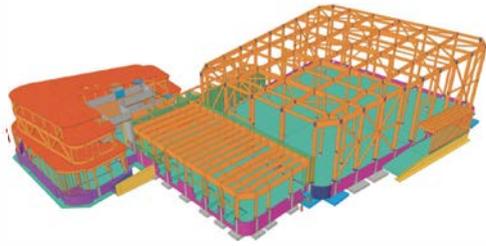
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TZMO Office, Logistics Centre, and Warehouse in Riga, Latvia

Structure: 803 m³ glulam; 347 m³ CLT

Architect: Vents Grietēns

General Contractor: Pilnsabiedrība 3A

**Timber structural design, glulam
manufacturing, glulam and CLT
assembly:** ZAZA TIMBER



Foto: Kārlis Buškevičs



Foto: Valts Verners Pērkons



Foto: Jānis Vēveris

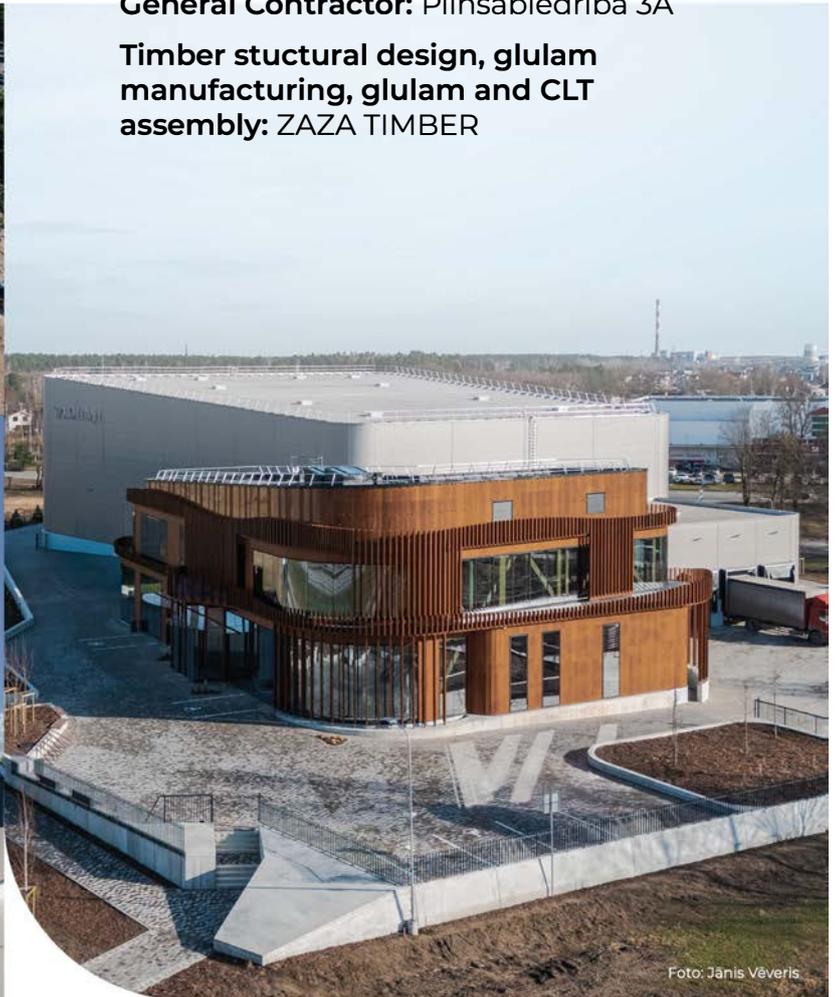


Foto: Jānis Vēveris

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T I M B E R

ZAZA TIMBER - timber structural
design, glued laminated timber
manufacturing, mass timber
construction

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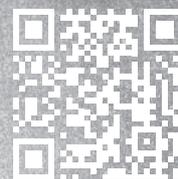
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A close-up photograph of a wooden surface, likely cross-laminated timber (CLT), with numerous water droplets of varying sizes scattered across it. The wood grain is visible, and the droplets are in sharp focus, highlighting the product's water-repellent properties.

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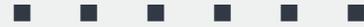
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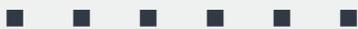
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SIMPSON

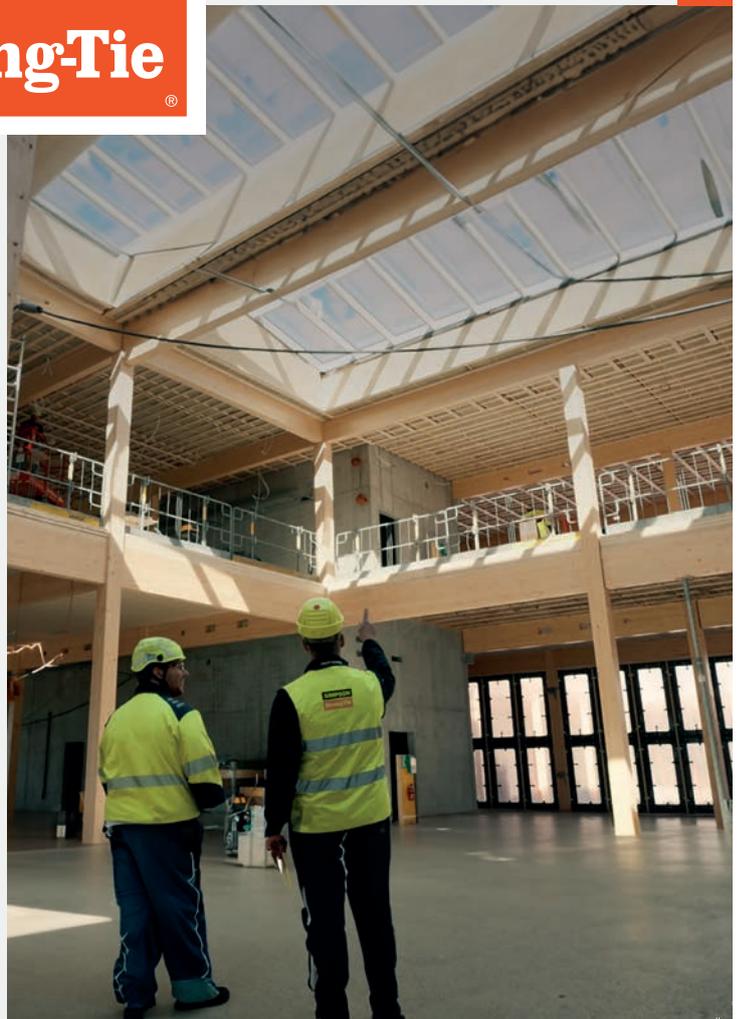
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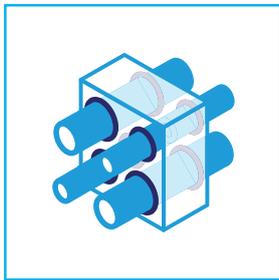
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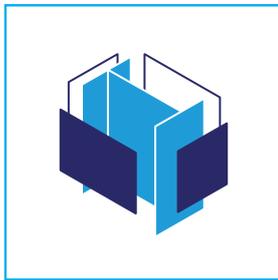


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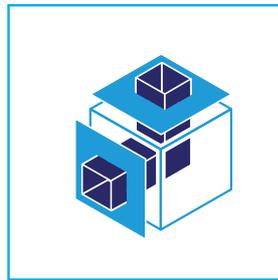
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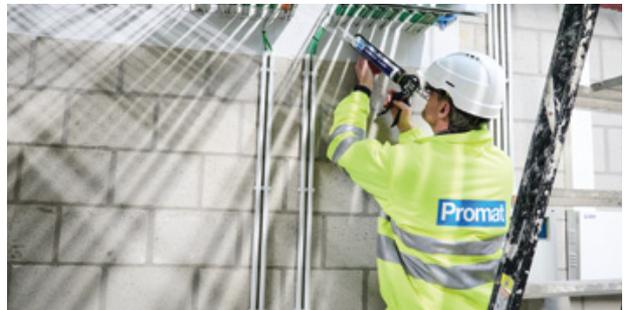
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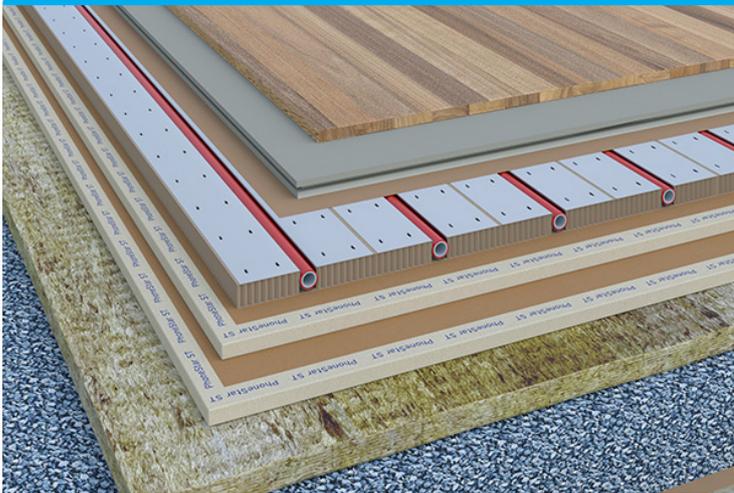
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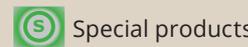
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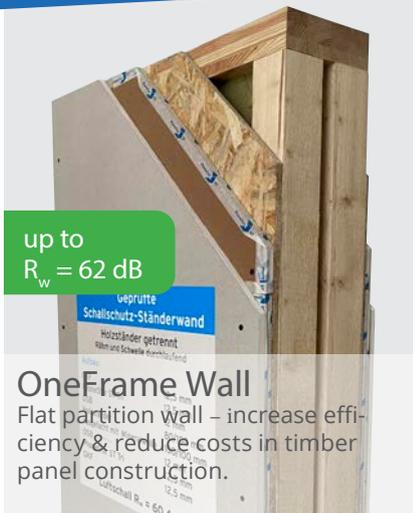
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