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CLT: WHERE HISTORY MEETS INNOVATION

CLT: GDZIE HISTORIA SPOTYKA INNOWACJĘ

Abstract

The environmental impact of construction is closely tied to the use of renewable and non-toxic materials that reflect Vitruvian principles of durability, functionality, and beauty. Wood, a natural and historically prominent building material, was gradually displaced by modern alternatives due to certain functional and technological limitations. However, the emergence of cross-laminated timber (CLT) has revived interest in timber architecture by overcoming many of these challenges. This paper examines the benefits of solid wood as a sustainable alternative to conventional, energy-intensive building materials. In the context of growing environmental awareness and increasingly strict regulatory frameworks, the selection of low-carbon, energy-efficient construction materials is gaining critical importance.

Keywords: CLT, sustainability, timber architecture

Streszczenie

Wpływ budownictwa na środowisko naturalne w dużej mierze zależy od doboru materiałów odnawialnych i nieszkodliwych dla zdrowia, które urzeczywistniają witruwiańskie zasady trwałości, użyteczności i piękna. Drewno – jako surowiec naturalny – przez stulecia stanowiło podstawowy materiał konstrukcyjny, jednak z biegiem czasu zostało wyparte przez nowocześniejsze rozwiązania technologiczne ze względu na swoje ograniczenia. Obecnie technologia drewna klejonego krzyżowo (CLT) odgrywa kluczową rolę w renesansie architektury drewnianej. Celem artykułu jest ukazanie potencjału zastosowania litego drewna jako niskoemisyjnej alternatywy dla tradycyjnych materiałów budowlanych. W obliczu rosnącej świadomości ekologicznej społeczeństwa oraz coraz bardziej restrykcyjnych regulacji prawnych, szczególnego znaczenia nabiera wybór rozwiązań przyjaznych środowisku, charakteryzujących się korzystnym bilansem energetycznym.

Słowa kluczowe: CLT, zrównoważony rozwój, architektura drewniana

1. REVIVAL OF WOOD IN THE 20TH CENTURY

In the 21st century, we are observing a return to choosing timber not only as a finish, but also as a structural material. This material, once the foundation of construction, had been pushed to the sidelines as more cost-effective and better-performing alternatives emerged, as well as due to technological and societal changes that took place in the late 20th century. New materials, such as ceramics and concrete, enabled the construction of both simple and more complex projects, as wood possessed its specific limitations. With the development of logistics and the availability of products and raw materials from distant locations, the importance of local materials, including timber, diminished.

The decline in timber construction was also fuelled by a belief in its limited durability and susceptibility to atmospheric conditions, pests, and – most importantly – flammability. Although these hazards still exist, modern technology makes it possible to counter them effectively through the use of appropriate insect, fungal, and mould-control measures, applied both preventively and as interventions. In parallel, eco-friendly methods of wood preservation based on natural, plant-based substances, such as essential oils, tannins, or extracts, are being developed, further strengthening wood's position as a sustainable material.[1]

Inadequately prepared, proofed and maintained wood has led to deformations, which negatively affected its perception as a building material. Most importantly, the belief in wood's lack of durability had become particularly entrenched, mainly due to numerous fires that consumed historic wooden structures, as well as contemporary cases of burning or decay of historic buildings. In the past, the effectiveness of available fireproofing agents was limited, and secondary proofing, carried out after the structure had been assembled, did not provide an effect equivalent to that achieved through impregnation carried out at the prefabrication stage. Today, modern fire protection methods enable the significant reduction of timber's flammability, creating a material that meets high safety standards.[2]

In the 20th century, timber construction predominated mainly in rural areas and small towns, primarily due to economic rather than ideological considerations. Over time, developers and owner-builders adopted a more pragmatic approach, choosing readily available materials and those which were easier to employ. In the case of working with timber, awareness of the material and carpentry skills were essential – both in terms of the construction of walls and wood trusses, as well as finishing details – whereas masonry techniques required less specialisation. The popularity of alternative materials was therefore influenced by the easier availability of craftsmen, or the potential to execute projects using the owner-builder model. In Poland, wooden construction persisted primarily in mountainous regions, where deeply rooted tradition and climatic conditions still contribute to material selection. These regions feature distinct roof forms with gabled and hipped roofs, extended eaves, and a solid foundation, mostly built using logs that play both a structural and aesthetic role.

The timber frame, especially the so-called Canadian framing system, is based on posts and beams filled with insulation and finished with wood panels. While this system allows for rapid assembly without a highly qualified crew, its durability is limited, and its resistance to extreme weather conditions is lower, as evidenced by the disasters experienced in North America.[3] Both technologies – logs and timber frames – have span limitations, which result in their use mainly in single-family buildings. They are rarely seen in service and commercial buildings, and their application in Poland remains marginal, except for mountainous regions and recreational and temporary architecture.

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[1] D. Ewart, P. Dhang, *Current development in wood protection against insect and fungal pests*, "CABI Reviews" 2016, vol. 11, art. no. 038, https://www.cabidigitallibrary.org/doi/10.1079/PAVSNNR201611038 (access: 14.07.2025).

[2] Y. Tsapko, V. Lomaga, O. Tsapko, *Multifactor method for evaluating the effectiveness of wood fire protection*, "Ukrainian Journal of Forest and Wood Science" 2022, no. 1, pp. 72–80. DOI: 10.31548/forest.13(1).2022.72-80.

[3] J. Smith, *All about timber framing: History, characteristics, joinery* [in:] MT Copeland blog, 17.09.2020, https://mtcopeland.com/blog/all-about-timber-framing-history-characteristics-joinery/ (access: 12.07.2025).

The contemporary state of the environment, climate change, and increasing urbanisation have prompted society – particularly the construction sector – to reflect on how projects that do not adversely affect pro-environmental values are designed and executed. The use of materials such as concrete, steel, or aluminium is still predominant, which places a significant burden on the environment both in terms of emissions during production and through the difficulties associated with their potential recycling. The return to wood as a renewable, healthy raw material with a negative carbon footprint appears to be the right answer to the needs of modern construction.

Modern approaches based on glued laminated timber technology offer a natural product with very good thermal and acoustic parameters, eliminating many of the previous limitations of wood as a construction material.[4]

Ill. 1. Assembly of a building using a prefabricated timber log system – massive wall elements laid in layers (left photo). Timber frame construction during assembly – a lightweight frame consisting of vertical and horizontal members (right photo), source: *Technology* [in:] EcoHauseMart, https://ecohousemart.com/technology/ (access: 14.07.2025)

Ill. 2. Delivery and assembly of CLT elements on the construction site using a crane, source: *What is cross laminated timber (CLT)?* [in:] Eugen Decker, https://www.eugen-decker.de/en/cross-laminated-timber.html (access: 14.07.2025)

[4] A. Stępień et al., *Sustainable construction – Technological aspects of ccological wooden buildings*, "Energies" 2022, no. 23, art. no. 8823, https://www.mdpi.com/1996-1073/15/23/8823 (access: 12.07.2025).

2. CLT – INNOVATION AND SUSTAINABILITY

The innovative use of solid timber emerged in the 1990s, in the form of prefabricated panels designed to replace traditional external and internal partitions – both vertical and horizontal – with simplicity and speed of assembly. Cross-laminated timber (CLT) is made from layers of coniferous wooden slats (usually spruce, pine, or occasionally larch) laid crosswise and bonded with formaldehyde-free glue under high pressure. Previously, only glue-laminated beams and columns were used, but the development of CLT technology has made it possible to create complete partition systems with a varied layer structure to suit structural requirements. This solution offers an alternative to energy-intensive and environmentally unfriendly conventional products. [5]

The development of solid wood technology can be traced back to Austria, one of the key countries in its popularisation. This is where leading manufacturers such as Binderholz, KLH Massivholz GmbH, Mayr-Melnhof Holz Group, and Hasslacher, known for their hundreds of completed projects and global presence in the wood processing sector, operate. In Austria, Switzerland, and the Netherlands, the use of wood is not just an expression of environmental concern, but also a pragmatic choice – the technology is readily available, cost-effective, and socially acceptable. Developers make informed decisions there, considering the benefits of wood use.

Sustainable development is the idea of planning and conducting economic, social and spatial activities in a way that meets the needs of the present generation without compromising future generations' ability to meet their own needs. It is based on three interrelated pillars: environmental, social, and economic.[6]

Ecological considerations determine both the natural and cultural context of buildings, and aim to reduce interference with the natural environment, improve the quality of the indoor environment, and reduce energy demand. Low-energy buildings are becoming increasingly important, and zero-energy buildings are becoming possible.

As a renewable material, wood has a negative carbon footprint, absorbing and sequestering CO_2, becoming a natural reservoir of this gas. By replacing conventional materials – which are high-emission – it provides further environmental benefits. At the same time, the use of chemicals is kept to a minimum during CLT production, and the product is free of volatile organic compounds.[7]

Sustainable design is based on an analysis of the full life cycle of a building: from raw material sourcing, through design, construction and operation, to potential demolition. It is guided by key questions: 'what materials' are used, as well as 'where are they from', and 'what is their energy consumption' – both in terms of production and logistics. CLT companies often follow the principle of 'from seedling to afforestation and processing', covering the entire forest management cycle, not just production.

Prefabrication reduces energy consumption at both the manufacturing and assembly stages. It facilitates the organisation of the construction process, reduces execution times, lowers

[5] R. Brandner et al., *Cross laminated timber (CLT): Overview and development*, "European Journal of Wood and Wood Products" 2016, vol. 74, pp. 331–351.

[6] L. Kamionka, *Architektura zrównoważone i jej standardy na przykładzie wybranych metod oceny*, Wydawnictwo Politechniki Świętokrzyskiej, Kielce 2012, pp. 21–24.

[7] R. Bergman et al., *The carbon impacts of wood products*, "Forest Products Journal" 2014, no. 7/8, pp. 220–231. DOI: 10.13073/FPJ-D-14-00047

the need for workers and machinery, and minimises noise and dust emissions. The lightness of the components allows for large-format production, easy transport, and assembly with lightweight equipment. Prefabricated units can incorporate building services solutions, reducing the scope for additional technical work. Exposing wooden surfaces, on the other hand, allows some of the finishing to be dispensed with.

Zero waste remains the guiding principle in the contemporary production of construction materials, and it is especially easy to implement in the case of wood. Up to 100% of the harvested raw material is processed into sawn timber or glulam, and the waste (bark, chips, sawdust) is used to produce biofuels, renewable energy, pressed board, or pallets. This approach enables climate-neutral production and the full use of resources. Technologists develop the components in such a way that the structures can be easily dismantled. Materials are combined so as to be separated and reused after a building's lifecycle has ended, which enhances energy performance and aligns with the principle of circularity.[8]

Social determinants are tied to the creation of healthy and comfortable spaces. As a natural material, wood has a multi-sensory impact – through touch, smell, and visual texture – which benefits the well-being and comfort of users. Studies confirm its positive effects on the immune and nervous systems, and the quality of rest and work. Unlike low-cost finishing materials, wood does not emit harmful substances and does not cause allergic reactions.

Economic considerations in sustainable construction require a new approach to a project's balance – considering not only construction costs, but also environmental impacts. Unlike traditional economics, which sees the environment as a source of 'free goods', sustainability emphasises reducing energy consumption, materials, emissions, waste, and transport needs.

3. CLT FOR THE ENVIRONMENT AND HUMANITY – MULTIPLE-CASE STUDY

Ill. 3. Bernardo Bader Architects, 'Haus am Moor', Krumbach, Austria, 2013, source: *House by the fens 2013* [in:] bernardo bader architekten, https://www.bernardobader.com/en/projekt/haus-am-moor-2 (access: 14.07.2025)

[8] M.H. Ramage et al., *The wood from the trees: The use of timber in construction*, "Renewable and Sustainable Energy Reviews" 2017, vol. 68, part 1, pp. 333–359. DOI: 10.1016/j.rser.2016.09.107.

The contemporary consumer of architecture is an informed user, with specific needs and expectations, and this is reflected in the increased popularity of timber architecture based on solid wood, especially CLT. Although these solutions are most commonly used in single-family housing, they are increasingly applied to multi-family housing and hotel and service buildings, whose typologies are converging both aesthetically and structurally. The technology is widely used where the high aesthetic quality of finished surfaces translates directly into user comfort. Developers who opt for these solutions are guided by functional considerations and environmental concerns, implementing ecological principles in everyday life as well.

Wood is also increasing in significance thanks to designers who consistently promote it and improve their craft in the process. Bernardo Bader, whose portfolio is largely based on wooden detached house projects that support a minimalist yet practical aesthetic and a sensitivity to local forms and details, is a good example of this.

'We transform existing typologies into something special. With joy and according to the method of finding – not inventing', states Bernardo Bader. This manifesto remains evident in relation to the scale and proximity of the proposed buildings and in the subtle inspiration from the existing natural and cultural context. Many of the Austrian architect's projects are interpretations of the so-called 'modern barn'. In the case of this type of building, CLT makes it possible to dispense with the trusses while retaining the pitched roof, constructed using two solid laminated timber partitions, as well as the exposure of the slope, giving the living space double the height.

Ill. 4. Bernardo Bader Architects + Adolf Bereuter, Kindergarten 'Am Schlatt' in Lustenau, Austria, 2020, source: *Bernardo Bader, Adolf Bereuter · Kindergarten "Am Schlatt" in Lustenau* [in:] Divisare. Atlas of Architecture, https://divisare.com/projects/445195-bernardo-bader-adolf-bereuter-kindergarten-am-schlatt-in-lustenau (access: 14.07.2025)

The above manifesto remains visible in Bader's own house in Krumbach. The House by the Fens is itself a very versatile example of a house that combines innovation and tradition. It also promotes CLT technology, fragmentarily combining it with architectural concrete technology. The starting point here was the local context of former farm buildings, and the proposed building adopted an elongated rectangular plan with a characteristic central recess in the space. The idea of reinterpreting the traditional threshing floor that separates the house from the outbuilding was decisive in creating this open area, which functionally separates the building into two parts. In this case, the leisure character of the space obtained is further emphasised by a terrace that extends towards the nearby forest.

The living area has an open plan and encompasses the ground floor with a kitchen in the centre, while the upper floor is defined by a hallway-type layout with rooms alongside it. The incorporation of the stairs, which variably combine the ground floor and the first floor by placing the day zone and a so-called studio as an additional small flat, is particularly distinctive here. The partitions, stairs, and carpentry solutions were made using locally sourced timber, which achieves a coherent overall effect. In contrast, the part of the structure that comprises the shaft and ceiling exposes the smooth structure of the concrete. Bader wanted the timber to be sourced from the region's private forests and cut according to the cycle of the moon to ensure greater hardness and density. [9]

In addition to house projects, Bernardo Bader's numerous designs also include service buildings in which CLT has both structural and aesthetic function. The extension of the Am Schlatt kindergarten in Lustenau occupies a special place here – it is a design that the architect defined as an example of 'the architecture of empathy'. He also stressed that he considered the original building by Burkhalter Sumi Architects, erected in 1994, to be a perfect work.

The original kindergarten is still regarded as an exceptional example of 1990s wooden architecture. After 25 years, there was a need to extend it. The new building is physically connected to the existing one, but both can operate independently. They are linked by their spatial layout and, most importantly, their approach to material – wood serving as a vehicle for architectural values. The new wing, although having a single level, offers a space with an increased height, and is designed in the spirit of minimalism, with austere detailing. In this way, it subtly complements the original mass, maintaining its character and spatial quality.[10]

The small house in Rossleithen, Austria, designed in 2017 by ,mia2 Architektur, is an inspiring and modern example of wood application and stands out in terms of its location in the Kalkalpen National Park, the largest forested area in Central Europe.

Ill. 5. mia2 Architektur ZT GmbH, 'Haus mit GIEBEL', Rossleithen, Austria, 2017, source: *Haus mit GIEBEL* [in:] mia2 Architektur, https://www.mia2.at/haus-mit-giebel (access: 14.07.2025)

[9] *House by the fens 2013* [in:] bernardo bader architekten, https://www.bernardobader.com/en/projekt/haus-am-moor-2 (access: 14.07.2025).

[10] *Bernardo Bader, Adolf Bereuter · Kindergarten "Am Schlatt" in Lustenau* [in:] Divisare. Atlas of Architecture, 13.07.2021, https://divisare.com/projects/445195-bernardo-bader-adolf-bereuter-kindergarten-am-schlatt-in-lustenau (access: 14.07.2025).

Rossleithen, located in the sunny Garstental valley, surrounded by mountain ranges, is known as a skiing centre. The project attracts attention with its massive, overhanging attic mass finished in black cladding, which contrasts with the natural colour of the ground-floor siding. The terrain on the hill has been used in the organisation of the space – the ground floor has been divided into two levels connected by steps. The lower section houses the entrance and living area, while the upper section features the kitchen, a two-storey-high dining area, and an exposed circular window behind the gable façade glazing. The entire structure was composed of prefabricated CLT elements, which enabled the creation of a spatially open layout and a high living area. CLT panels were also used in the staircase, doors, and built-in furniture, creating a coherent wooden structure organised around a central block.[11]

The potential for the application of CLT technology remains particularly evident in projects that represent an out-of-the-box approach through their form or space creation. One case in point is a house and office in Mödling, designed by JOSEP in cooperation with Atelier Haumer, and whose distinctive feature is a star-shaped plan and a levitating effect.

Ill. 6. JOSEP ZT GmbH and Atelier Haumer, '52 Kubik', Mödling, Austria, 2017, source: https://josep.at/52-kubik (access: 14.07.2025)

The authors of the project, who named it '52 Cubic Wood', emphasised that modern timber construction can make a significant contribution to reducing the carbon footprint. The number 52 refers to the volume of timber – 52 cubic metres – used in the construction of this particular house. According to the European Forest Institute, buildings generate as much as 39% of global carbon emissions over their entire life cycle. The use of wood is a viable strategy for mitigating climate change: every tonne of wood used instead of concrete reduces CO_2 emissions by two tonnes.

The designers chose to use CLT, driven by its capacity to achieve large spans and maximum ground-floor opening with a minimum number of supports. This structural solution allowed the axial view to be maintained across the entire width of the building – a transparency and levitation effect desired by both the authors and the client.

The house has a residential function and at the same time a working space, linked to the horticultural activity, which has determined its strong openness to the outside, green environment. In the building mass, we can see the glazed façades of the ground floor, while the first

[11] *Haus mit GIEBEL* [in:] mia2 Architektur, https://www.mia2.at/haus-mit-giebel (access: 14.07.2025).

floor consists of solid surfaces, finished with an openwork cladding of wooden lamellae. Of particular note are the side façades, made of mirrored glass panels, which reflect the surrounding vegetation and reinforce the integration with the landscape. The day and night zones have been placed on the first floor, around a central star-shaped plan, where each 'arm' has a different function.

The interiors feature solid-wood structural elements. Some of the furnishings – including the staircase and doors – were made from the same sandwich panels, a consistent development of the material language of the design.[12]

'Puukuokka Housing Block', designed by OOPEAA, is the first eight-storey timber residential building in Finland. Completed in 2015, it was honoured with the Finlandia Prize for Architecture and the Resident Act of the Year award, among others, and was shortlisted for the EU Mies Award.

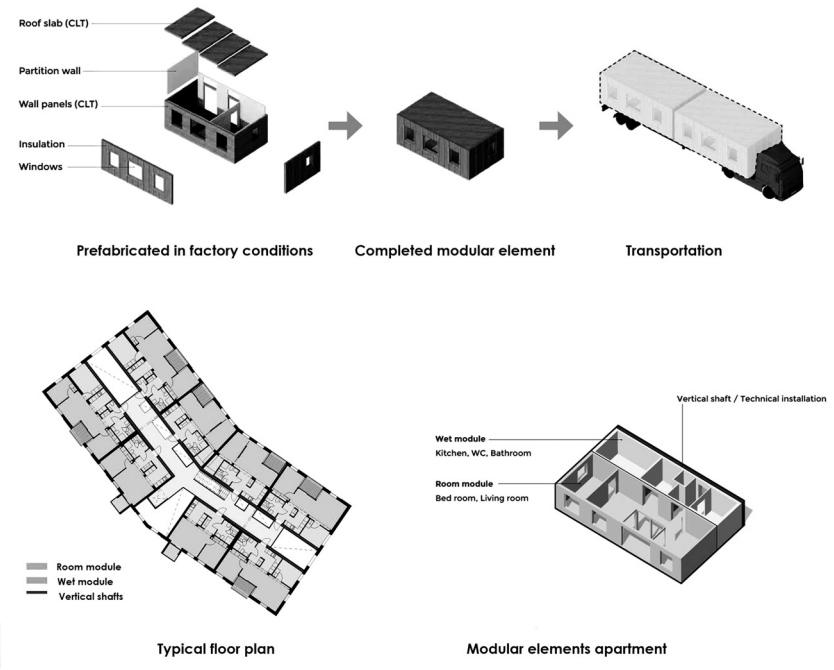
Ill. 7. OOPEAA. 'Puukuokka Housing Block', Jyväskylä, Finland. 2015–2018, source: *Puukuokka Housing Block* [in:] OOPEAA, https://oopeaa.com/portfolio/puukuokka-housing-block/ (access: 14.07.2025)

The 'Puukuokka Housing Block' is a pilot project for an innovative lease-to-own financing model that aims to support sustainable social development by promoting lasting, integrated communities. The scheme involves making a down payment of 7% of the dwelling's price, which enables the acquisition of a state loan and subsequent gradual ownership of the dwelling through rent payments spread over twenty years. For the design team, the project was also an opportunity to research the application of CLT-based 3D modules. The project focused on exploring the potential of CLT modular prefabrication, whose replicability was intended to serve both to reduce environmental impact and to increase the availability of housing in terms of cost. The architects aimed to create a complex that combined a sense of privacy and warmth familiar to a single-family home with the semi-public character of a community space.

The use of prefabrication reduced construction time to six months and minimised exposure to the weather. The modules were made at a local factory in Hartola, less than two hours away from the site, which lowered the carbon footprint. The building's load-bearing structure and frame were constructed using local spruce timber, introducing not individual elements but rather whole dedicated modules composed of interconnected vertical and horizontal partitions. Each flat consists of two modules, one comprising a living room, a balcony, and a bedroom, and the other comprising a bathroom, a kitchen, and a hallway.

[12] *52 Kubik* [in:] JOSEP ZT GmbH, https://josep.at/52-kubik (access: 14.07.2025).

The development complex consists of three masses, 6 to 8 m high, built two years apart. The architects alluded to the geometry of nature through a subtle yet expressive jagging of forms, while leaving clear divisions between the flats, making use of the technical and aesthetic qualities of CLT. By dividing the building into three independent masses, it was possible to introduce landscaping in between, creating a clear and, at the same time, attractive sequence.



Ill. 8. OOPEAA. 'Puukuokka Housing Block', Jyväskylä, Finland. 2015–2018. Building constructio and logistics schemes based on the CLT modular system,source: *Puukuokka Housing Block* [in:] OOPEAA, https://oopeaa.com/portfolio/puukuokka-housing-block / (access: 14.07.2025)

The complex has a partially underground car park storey, and to preserve the natural hilly landscape, most of the rocky soil was left undisturbed wherever possible, while the potential of existing vegetation was also used. Introducing a CLT structure enabled the formation of an inter-unit space that, in a peculiar way, resembles an interpretation of hallways as approaches to each unit, where, through holes in the floors, these spaces resemble footbridges and transform the space into an atrium with an abundance of light from above that explores each level. This idea also contributes to energy performance, as this is a semi-warm area where the insulating properties of solid wood allow for independent temperature regulation. The use of prefabricated wooden modules allowed the heating, water, electricity, and ventilation systems to be integrated into the corridor wall structure, providing easy access for maintenance. This solution also allows for efficient spatial organisation.[13]

[13] *Puukuokka Housing Block* [in:] OOPEAA, https://oopeaa.com/portfolio/puukuokka-housing-block/ (access: 14.07.2025).

Another example worth analysing is the residential development '85 Social Dwellings' in Cornellà, which reached the final list for the EUmies Award 2022 thanks to Peris+Toral Arquitectes

Ill. 9. Peris + Toral Arquitectes, '85 Social Dwellings' in Cornellà de Llobregat, Spain, 2021, source: *Peris+Toral Arquitectes, 85 Social Dwellings in Cornellà* [in:] Divisare. Atlas of Architecture, https://divisare.com/projects/455123-peris-toral-arquitectes-jose-hevia-85-social-dwellings-in-cornella (access: 14.07.2025)

The building is a mass with a courtyard, distinguished by an open ground floor with a minimalist portico. The courtyard leads to the main circulation cores and creates a transition between public and community spaces, transforming the courtyard into a central plaza conducive to the integration of residents. The staircases are arranged at the four corners of the courtyard, encouraging daily meetings and neighbourly contacts. The floors are designed in a repeating layout – the access to the units is via private balconies, which surround the internal space. An additional outdoor terrace completes the spatial sequence, introducing light, ventilation, and visual openings.

The unit layout, which completely eschews hallways, with only the sanitary spaces partitioned off, is an interesting spatial solution. This has allowed maximum use and flexibility of usable space. Four or five units were clustered around each circulation core, providing all units with cross-ventilation and dual orientation relative to the cardinal directions. The units consist of five or six modules, depending on the number of bedrooms. The units' open kitchens are centrally located, which symbolically abolishes the traditional gender division in household chores. The minimal number of structural walls – resembling cruciform columns in plan – allows the space to be freely partitioned. When functions are not clearly assigned, the interior layout facilitates creative adaptation.[14]

The final project is 'Lumber 4,' by Oslotre Architects, a six-storey service building that offers a variety of leasable spaces designed for future adaptation, featuring a strong wooden technological and aesthetic expression. Construction was completed in a relatively short period of just twelve months compared with traditional methods. The proposal was recognised as the best office building of the year in the medium-building category at the Architizer A+ Awards 2024.

The setback ground floor is the commercial level, with the five floors above it assigned to office spaces. The structure is based on pre-existing circulation cores, and the floors use

[14] *Peris+Toral Arquitectes, 85 Social Dwellings in Cornellà* [in:] Divisare. Atlas of Architecture, https://divisare.com/projects/455123-peris-toral-arquitectes-jose-hevia-85-social-dwellings-in-cornella (access: 14.07.2025).

a composite construction of concrete and laminated timber, thus meeting fire and acoustic standards and fulfilling industry guidelines. The angled pillars of the structural system on the ground floor facilitate vehicle access. An atrium with an internal staircase made of solid wood was introduced between the third and fourth floors. The introduction of timber works well in providing suitable acoustic and thermal insulation parameters, ensuring it remains warm in winter and cool in summer. In addition, wood-wool panels were introduced in acoustically sensitive spaces. The exposed electrical, sanitary, and air-conditioning systems are housed in aesthetically pleasing light-beige covers.

Ill. 10. Oslotre Architects, 'Lumber 4' was the first commercial timber building in southern Norway, source: M. Montagnana, *Office building Lumber 4. Innovation comes from wood* [in:] Arkitectureonweb, 12.11.2024, https://www.arkitectureonweb.com/en/-/projects/office-building-lumber-4-innovation-comes-from-wood (access: 14.07.2025)

The building's structure consists of solid timber elements, with glued-laminated timber columns and beams. The bespoke façade solutions are also prefabricated and made to order. Together with the colour of the greenery, they give the building a unique effect. The façade is made up of curved pine timbers, coated with green paint. The canopies over the curved elements are straight, creating a curved shadow on the panel that anticipates the so-called 'patina of time'. Over the course of further use, the paint under the shade will age, resulting in a change in the appearance of the façade, with lighter and darker curved areas appearing. The façade solution was custom-designed specifically for this project, simultaneously including wood-fibre insulation and impregnation. Large floor-to-ceiling windows provide a wide view and an abundance of natural light and – aesthetically speaking – create a distinctive mosaic on the façade based on a solid-empty alternating sequence.

Lumber 4 demonstrated that wooden buildings can be constructed to a technical standard that is competitive with concrete and steel structures, while the wood architecture positively impacted the project's reception, as it was rapidly commercialised after construction finished. In addition to having a more favourable energy balance, the building has reduced greenhouse gas emissions by 53% thanks to a high level of prefabrication and innovative eco-friendly solutions. According to EU taxonomy, these solutions are considered environmentally friendly. [15]

[15] M. Montagnana, *Office building Lumber 4. Innovation comes from wood* [in:] Arkitectureonweb, 12.11.2024, https://www.arkitectureonweb.com/en/-/projects/office-building-lumber-4-innovation-comes-from-wood (access: 14.07.2025).

4. CONCLUSIONS

Sustainability is an indispensable part of the functioning of modern society. In this context, wood, as a renewable, aesthetically pleasing, and healthy material, meets the growing needs of builders and users looking for sustainable, eco-friendly, and comfortable building solutions. CLT technology enables the construction of buildings of high environmental quality, offering numerous benefits: from reduced CO_2 emissions and shorter construction times to improved occupant comfort. The visible structure of wood, along with its physical and chemical properties, contributes to the creation of harmonious spaces that support the health and well-being of users.

CLT technology provides design flexibility, enabling the creation of both modern and traditional architectural forms. Thanks to prefabrication, it remains possible to achieve a high degree of manufacturing precision and reduce finishing costs. In addition, these structures are characterised by favourable energy balance and long-term durability. The analysis of project cases presented demonstrates that modern and innovative wooden construction combines aesthetic, utilitarian, and environmental values. The examples presented in this article show that CLT can play a key role in the future of sustainable construction.

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[1] *52 Kubik* [in:] JOSEP ZT GmbH, https://josep.at/52-kubik (access: 14.07.2025).

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