AkzoNobel

# The case for wood in more sustainable buildings

A study exploring the carbon footprints of different building materials and explaining how to specify wood in building projects

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# Introduction

As the built environment embraces more sustainable and innovative ways of designing and constructing buildings, the materials we choose have never mattered more.

Wood is emerging as one of the most promising solutions, offering a combination of low embodied carbon, renewability, durability and design flexibility. Yet despite growing evidence of its environmental and performance advantages, it remains under-utilized. This white paper explores the data behind wood's sustainability credentials, examines the role of paints and protective coatings in maximizing long-term performance, and shows why greater adoption of timber for creating more sustainable buildings is possible – and essential.

# Executive summary

The emissions associated with building materials and construction over a building's lifetime – otherwise known as embodied carbon – are rapidly becoming as important as operational emissions from energy use in building design. As a result, selecting materials for façades and window frames has become a significant factor in reducing a building's climate impact.

Wood and modern engineered timber systems can play a powerful role in reducing embodied carbon as they are renewable, biogenic and, in typical building applications, have a significantly lower cradle-to-grave footprint than aluminum, PVC or steel. When responsibly sourced, well detailed and properly protected, wood provides lasting durability, robust performance and distinctive architectural quality.

To quantify the differences, AkzoNobel, in collaboration with the University of Amsterdam (UvA)[1], conducted a comparative lifecycle assessment of representative façade panels and window frames, including both the substrate and its paints and coatings. The study used market-average Environmental Product Declarations (EPDs) for wood, aluminum, steel, PVC, glass, natural tiles, bricks and natural stone, combined with AkzoNobel Product Carbon Footprint data for paints and coatings, for a wide range of substrates. AkzoNobel develops solutions for various substrates included as part of the assessment, which provides unique insights in the carbon footprint of different coated building materials. Conservative assumptions were applied for maintenance and end-of-life scenarios.

### The assessment found that:

- The substrate is the dominant driver of a total carbon footprint; coatings contribute a relatively small share (4% to 37%), even when maintenance is included.
- In the scenarios studied, wood-based façades and window frames have lower lifecycle carbon emissions than PVC, aluminum, steel and other alternatives.
- Longer-lasting systems, including high durability paints and coatings, may have slightly higher initial carbon emissions, but reduce lifetime carbon emissions by extending service life and reducing the need for premature replacement.

These findings highlight a central insight: the real value of a coating lies not in its own carbon emissions, but in its ability to protect the substrate and preserve its technical service life. Durable coatings are therefore a critical enabler of sustainable timber construction, not a barrier. However, this benefit can be overlooked if building managers, specifiers and contractors focus only on initial embodied carbon.

This white paper summarizes the assessment, explains the broader benefits of wood, and outlines how to specify and protect timber in façades, windows, interiors and supporting structures using modern industrial and decorative paints, coatings and adhesive technologies. It also includes case studies to illustrate how these principles work in practice.

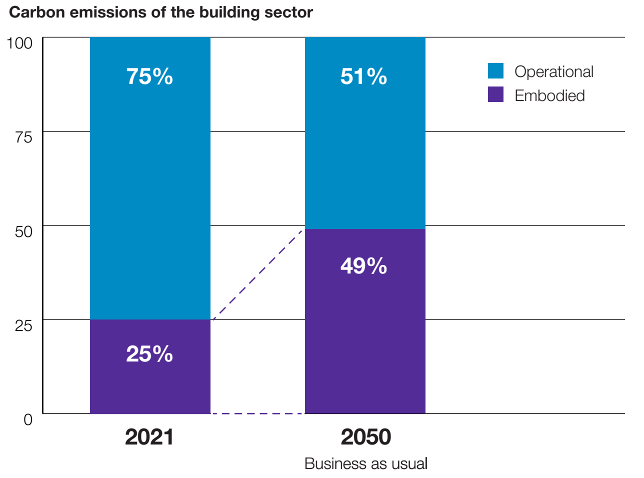
[1] See reference page at the end of this document

# From operational **to embodied carbon**

The buildings and construction sector accounts for around 37% of energy and process-related $CO_2$ emissions globally, making its decarbonization a defining priority for limiting global warming.[2] Efforts to make buildings more sustainable have traditionally concentrated on operational performance. Better insulation, tighter envelopes (the physical shell separating a conditioned indoor space from the outside environment), high efficiency heating, ventilation and air conditioning (HVAC) systems, LED lighting and renewable energy have reduced the energy use and therefore operational emissions of many new buildings. In some markets, operational emissions per square meter are now declining steadily.[3]

## Projected contributions from embodied and operational carbon within the building sector

From 2021 to 2050 with business as usual projections




Under business as usual, embodied carbon will contribute nearly half of all building emissions by mid-century.

Source: [2.1 Embodied versus operational carbon emissions in buildings]

As this happens, the relative importance of embodied carbon increases[4]. Embodied carbon covers all greenhouse gas emissions associated with materials and construction: extracting raw materials, manufacturing products, transporting them to construction sites, assembling them into buildings, maintaining them and, eventually, dismantling or disposing of them. For high-performing new buildings, embodied carbon can represent a large share of total lifecycle emissions – in highly efficient new buildings, often half or more of whole-life emissions – especially in the first decades.[5]

Regulation and market expectations are changing in response. In the European Union, the Green Deal and related legislation (such as the Declaration de Chaillot)[6] are driving a shift towards whole-life carbon thinking. Several countries now require lifecycle assessments for larger buildings, and some have introduced embodied carbon benchmarks or caps.[7] Cities and regions are experimenting with similar measures. Voluntary green building certifications such as LEED, BREEAM and DGNB increasingly reward the use of low carbon materials and timber.[8] Corporate climate commitments, particularly those aligned with the Science Based Targets initiative (SBTi), put pressure on developers and contractors to reduce emissions arising from the materials they buy and install.

In this evolving landscape, material choices at the design stage are critical. Switching from PVC to timber window frames, or from steel cladding to wood, can have a measurable effect on a building's embodied carbon. They also influence operational performance, aesthetics and user experience. Design teams therefore need robust data, not only on individual products, but also on complete systems over their service lives.

Wood is an essential consideration. Long used in traditional construction, it is being reinvented through engineered products such as cross-laminated timber (CLT), glue-laminated timber (glulam) and laminated veneer lumber (LVL). These materials allow timber to be used as a structural building material in mid-rise and high-rise buildings traditionally built from concrete and steel. Combined with a better understanding of detailing, they have the potential to deliver both a low carbon footprint and a long service life.

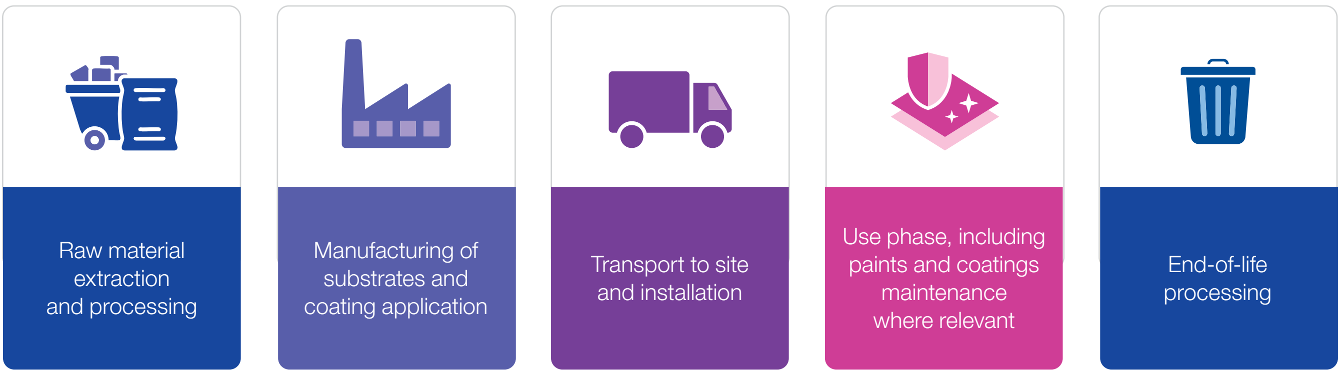
[2-8] See reference page at the end of this document

# **Lifecycle assessment** of building materials and their coatings

To understand how timber systems and their coatings perform relative to traditional alternatives, AkzoNobel undertook a focused lifecycle assessment of building materials and their coatings, in collaboration with the University of Amsterdam (UvA).[1]

It concentrated on two building elements where timber is compared with other typical building materials: façade panels and window frames. In the case of window frames, glazing is excluded so the focus is on the frame components themselves. The average glazing contribution from Environmental Product Declarations (EPDs) is removed from all datasets to ensure a consistent basis for comparison.

The functional unit is one square meter of finished façade panel or window frame over a defined reference service life. For each configuration, the assessment considers the full cradle-to-grave cycle, including:




Substrate data is drawn from publicly available EPDs. These are prepared according to standardized methodologies, such as EN 15804, and verified by independent bodies. For this assessment, market average EPDs are used for the substrates in common use for each element: wood, aluminum and PVC for window frames; and wood, aluminum, steel, glass, ceramic tiles, natural stone and brick for façade panels. Using market average rather than best-in-class EPDs avoids skewed comparisons between exceptional products and provides a realistic picture of typical practice, so that timber is compared against the full range of materials specified for each application.

Paints and coatings data comes from AkzoNobel's Product Carbon Footprints (PCFs), which are calculated in line with ISO 14067 and harmonized with the Together for Sustainability PCF guidelines. These reflect real coating formulations, energy use and supply chains, rather than generic emission factors, including generic coating maintenance requirements.

[1] See reference page at the end of this document

**To ensure comparability and avoid overstating any particular material's advantages, the assessment uses conservative assumptions:**

- Glazing is excluded from all scenarios for window frames.
- Façade panels are assumed to be coated on both front and back, doubling coating quantities per square meter.
- At end-of-life, all carbon in materials – including biogenic carbon in wood – is assumed to be released into the environment as $CO_2$. No credit is given for long-term carbon storage or delayed emissions.
- Only wood substrates are assumed to receive coating maintenance during the reference period; the non-wood substrates are assumed to remain within acceptable performance without recoating.
- Recycling rates reported in EPDs are not explicitly modelled in the comparative scenarios, keeping the focus on basic material and coating contributions.
- Coating service life is represented with an 80:20 distribution: approximately 80% of coated elements reach the lower limit of the service life range, while 20% reach the upper limit under optimal conditions.

Within this consistent framework, the assessment compares the total carbon footprint of different substrate/coating combinations and highlights where the most significant emission reductions can be achieved from a material and coating point of view. The study focuses on carbon footprint; other environmental impact categories (such as water use, eutrophication or toxicity) are outside its scope.

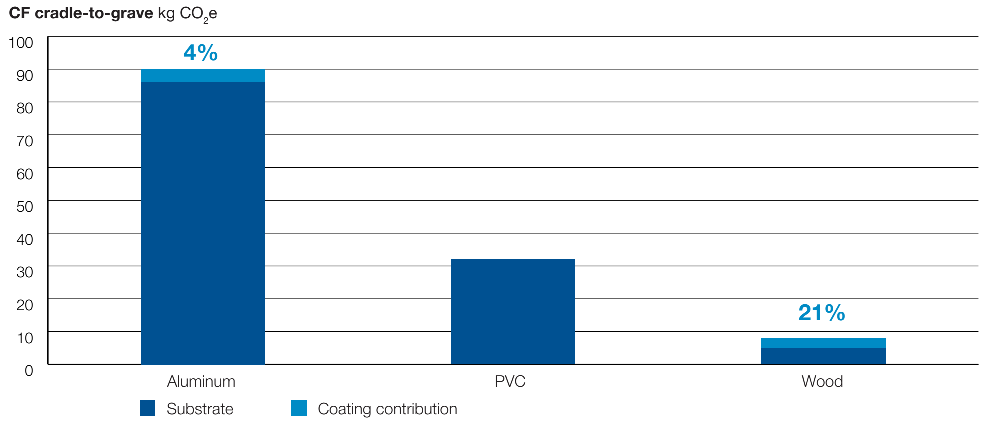
Atchugarry Museum of Contemporary Art, Manantiales, Uruguay

# What the **assessment reveals**

The results leave little doubt about where the main leverage lies. In both façade panels and window frames, the substrate is the dominant driver of cradle-to-grave carbon footprint. Coatings, while indispensable for protection and aesthetics, represent a relatively modest share of total emissions.

For wooden window frames, coatings account for around 21% of total emissions over the reference life; for aluminum window frames, the figure is about 4%. The rest comes from metals and other materials used in the frames themselves.

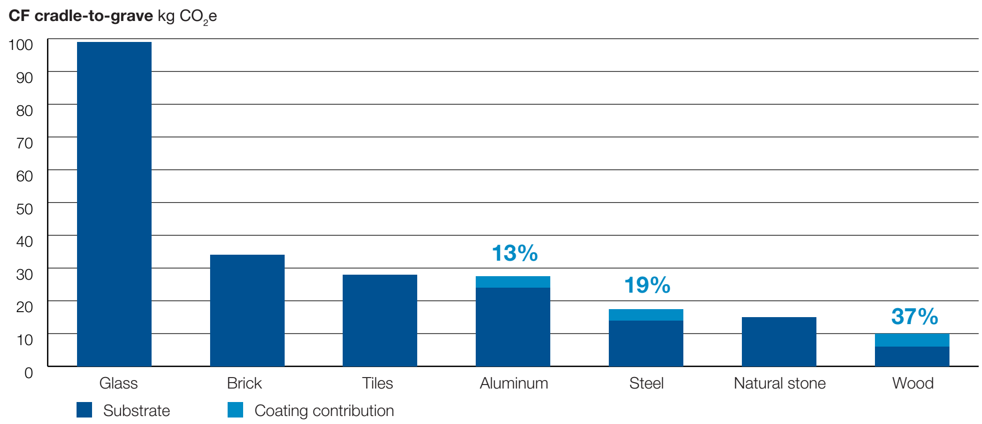
## Coating contribution in window frames




Coating contribution in window frames from cradle-to-grave

For façade panels, the coating contributes a larger share of total emissions because their surface-area-to-volume ratio is higher. As a result, the coating accounts for approximately 37% for wooden façade panels, 19% for steel panels and 13% for aluminum panels. Despite this increased contribution, the substrate remains the dominant source of emissions in all cases.

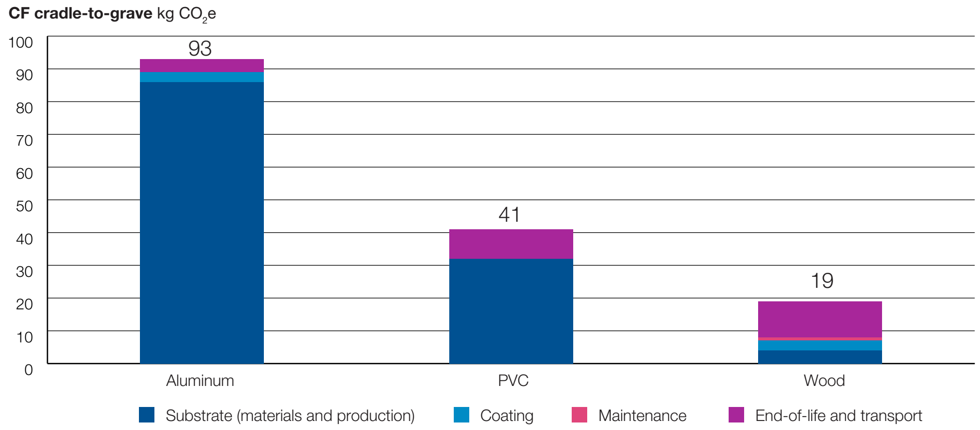
## Coating contribution in façade panels




Coating contribution in façade panels from cradle-to-grave

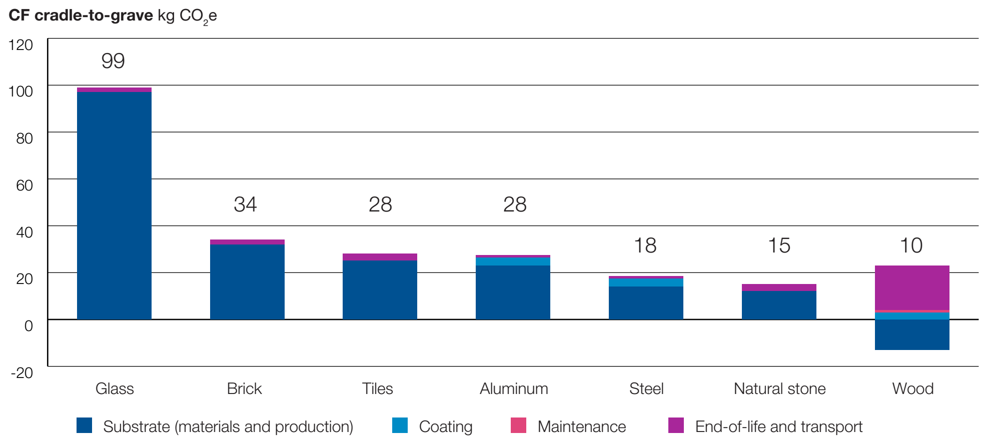
When the substrates are compared directly, wood comes out as the lower-carbon option in the scenarios assessed. Timber-based façade panels and window frames have lower cradle-to-grave carbon footprints per square meter than aluminum, steel or PVC equivalents, even though coating maintenance is included for wood and not for metals.

## Carbon footprint impact at different lifecycle stages in window frames




Carbon footprint impact at LCA stages in window frames

## Carbon footprint impact at different lifecycle stages in façade panels




Carbon footprint impact at LCA stages in façade panels

These findings align with a wide body of independent research that identifies timber substitution as an effective strategy for reducing embodied carbon in buildings. A 2025 study by Arup for the UK government, analyzing 11 representative building archetypes, found that increasing timber use can cut lifecycle embodied carbon by up to around 9% at the whole-building level, with reductions of up to roughly 35% in the structural frame and 20% in the façade.[9]

[9] See reference page at the end of this document

The assessment also sheds light on the role of durability. High-durability systems – for example, timber cladding protected by advanced coating systems - may have slightly higher initial carbon footprints because they might use more coating material or higher-quality, higher-performing coatings. However, these extend maintenance and repair intervals and reduce the likelihood of premature replacement. Over a 30–50-year period, the cumulative effect is lower total carbon emissions, less waste and fewer interventions.

This highlights an important principle: when evaluating coatings, it is not sufficient to consider only their carbon footprint per liter or kilogram. The true value of a coating lies in its ability to preserve the life of the substrate itself. By protecting wood against moisture, UV radiation and wear, coatings keep elements in service longer, reduce the need for new materials and allow for refurbishment and reuse rather than early disposal.

## From a practical standpoint, the assessment suggests that:

Choosing wood instead of aluminum, steel or PVC for façades and windows is often the most effective way to lower embodied carbon, within the boundary conditions studied and assuming other variables (such as the type of glazing used) remain comparable.

Investing in robust, long-lasting systems – both in terms of materials and coatings – is a sound strategy for reducing lifetime carbon emissions and total resource use.

Coating choices should emphasize durability and compatibility with timber, rather than focusing solely on minimizing the coating’s own carbon footprint.

04

# **Why wood offers more** than a carbon advantage

## While carbon reduction is a key driver, wood's appeal in modern buildings extends beyond its environmental profile.

Visually and in terms of tactility, wood brings warmth and character to façades and interiors. Exposed timber surfaces can make spaces feel more welcoming and inviting than those dominated by glass, metal and concrete. This is particularly valued in homes, schools, offices, leisure venues and healthcare environments, where the comfort and well-being of the occupants are paramount. A growing body of psychophysiological research links visible wood surfaces to measurable reductions in stress – including lower heart rate, blood pressure and sympathetic nervous system activity – with documented benefits in offices, classrooms and healthcare settings.[10, 11, 12]

Wood also supports biophilic design – the integration of natural elements into built environments. Research suggests that exposure to natural materials can help reduce stress and improve perceived comfort.[13] In combination with other design elements, such as plants and natural light, timber contributes to spaces that feel healthier and more calming.

From a technical perspective, engineered timber products such as CLT and glulam[14] provide a high strength-to-weight ratio. This allows structures to be lighter than equivalent concrete or steel designs, which can reduce foundation requirements and simplify transport and assembly. Its relatively low weight also makes timber well suited to vertical extensions ("topping up" existing buildings) in dense urban markets where ground space is limited. Prefabricated timber elements are produced in factory conditions with high precision, enabling rapid on-site installation and reducing construction waste.[15]

Thermal bridging occurs when a more conductive material creates a path through a building's insulation, letting heat flow. Thermally, wood has lower conductivity than metals[16], which reduces thermal bridging and supports energy efficiency in buildings. Timber frames and cladding systems can be combined with insulation and airtightness strategies to meet demanding energy performance targets.

These properties make wood particularly attractive for projects that aim to combine climate performance, occupant well-being and expressive architecture. With appropriate fire protection and regulatory frameworks, timber is increasingly used not only in low-rise buildings, but also in mid-rise and even high-rise projects.[15]

[10-16] See reference page at the end of this document

Hotel Jakarta, Amsterdam, the Netherlands

# Specifying and protecting wood in practice

To fully realize wood's potential, specifiers need to be confident that timber elements can meet performance requirements over their intended service life. This confidence comes from selecting the right products and coating systems for the application, supported by robust protection strategies and proven, well-supported product ranges.

For façade systems, this starts with choosing suitable timber products for the exposure and design life. In many cases, softwoods protected by industrial coatings perform well, especially in ventilated rainscreen configurations. In harsher climates or exposed conditions, modified wood or naturally durable species may be appropriate. Design detailing is critical – avoiding horizontal surfaces where water can sit, providing drainage and ventilation behind cladding, protecting end grain and ensuring joints shed water rather than trap it.

In window and door systems, dimensional stability and protection of vulnerable areas are key. Engineered profiles – laminated or finger-jointed – can reduce movement and improve coating performance. Industrial finishing in controlled environments ensures consistent film thickness and curing. Combined with good detailing (drip edges, seals, proper installation), these measures support long service life.

Centrocesal building, Quito, Ecuador

Interior timber elements are generally less exposed to weathering but must withstand mechanical wear and, in some cases, high humidity. Coatings here focus on abrasion resistance, cleanability and low emissions. Waterborne interior coatings with low volatile organic compound (VOC) content support good indoor air quality, an increasingly important criterion in green building certifications such as WELL.

Across these applications, coating technology has advanced. Industrial wood coatings are increasingly shifting from traditional solvent-borne coatings to waterborne and UV-curable technologies, helping to reduce VOC emissions. UV-curing systems – especially those using UV-LED technology – offer fast processing, lower energy consumption and elimination of traditional mercury-based lamps. These systems are well suited to high-volume production of cladding, window components and interior panels.

For existing buildings, decorative paints applied on site are the primary maintenance tool. Modern exterior paints for wood are designed to provide long maintenance intervals and strong resistance to UV radiation and moisture. Opaque systems generally offer the longest protection because they shield wood from sunlight effectively; translucent systems highlight the wood's natural grain but often require more frequent maintenance in highly exposed locations. Maintaining building surfaces such as wooden façades and selecting higher-reflectance (lighter) colors can help reduce surface temperatures and contribute to mitigating the urban heat island effect.

Concerns about frequent repainting are often based on older experiences or poorly detailed systems. With high-quality coatings, appropriate wood species and good detailing, maintenance intervals of a decade or more are achievable for many timber façades and windows. Over a building life of 30 to 50 years, this translates into a manageable amount of maintenance activity. When planned in advance, this can be integrated into a building's lifecycle strategy in much the same way as any other periodic care and upkeep.

Throughout, the guiding principle remains: coatings should be chosen and designed for their ability to extend the life of the timber elements they protect. In doing so, they help deliver both durability and lower lifetime emissions.

06

# Illustrating the approach

While this white paper focuses on principles and assessment results, real projects bring those principles to life. The following case studies help demonstrate how timber, paints and coatings, adhesives and thoughtful design combine in practice

## Domaine de Montcel luxury hotel, Jouy-en-Josas, France, 2025

- The 18th century building was renovated in 2025, with more than 100 timber windows and doors being installed that benefit from a 15-year warranty, marrying old existing and new wooden façade elements to keep the buildings authenticity

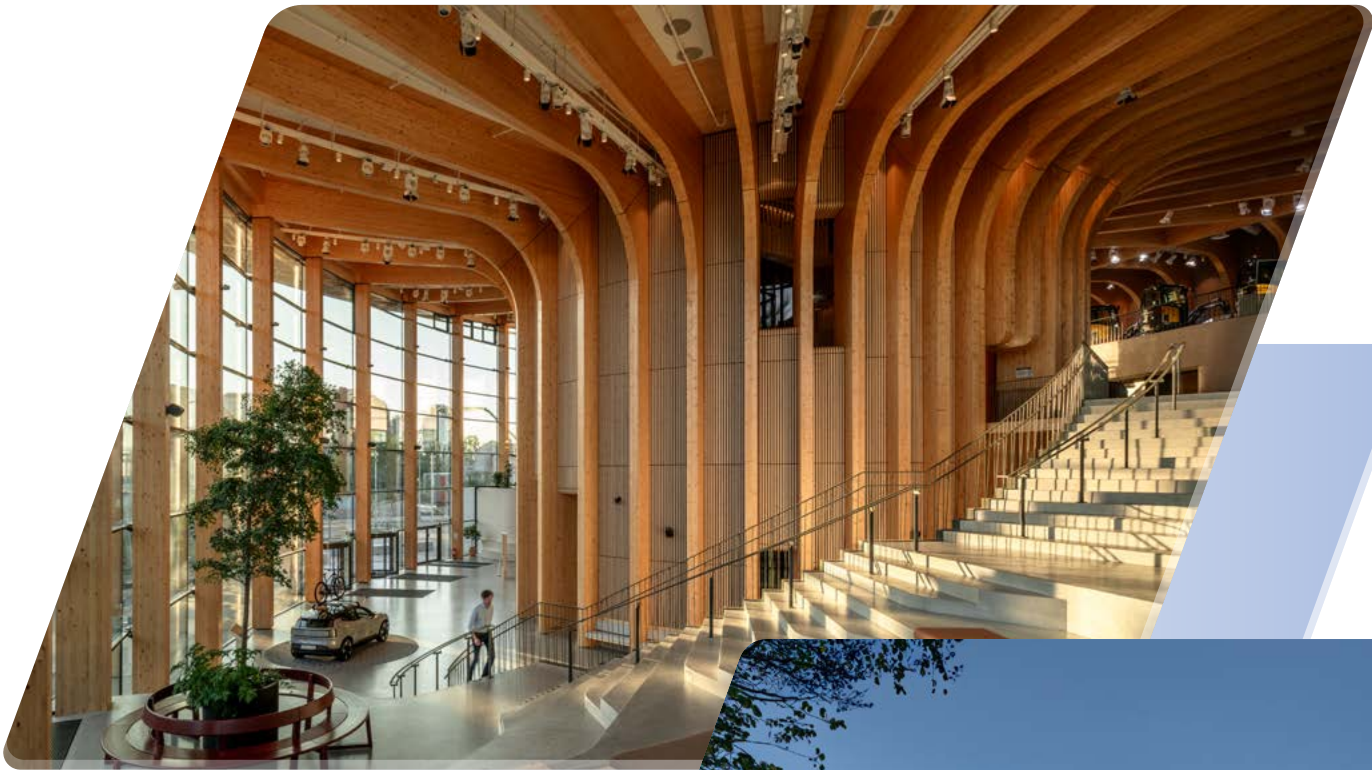
- Other companies involved:
  – Atulam (timber fabricator)
  – Agence Européenne de Fenêtres (traditional timber frame installer)
  – Le groupe ACAPACE in partnership with SOFIVAL (project owner/real estate developer)
  – Frédéric Didier, agence 2BDM, Chief Architect of Historic Monuments and Consulting Architect for the Palace of Versailles
  – Ll’agence Franck Neau, landscape architect

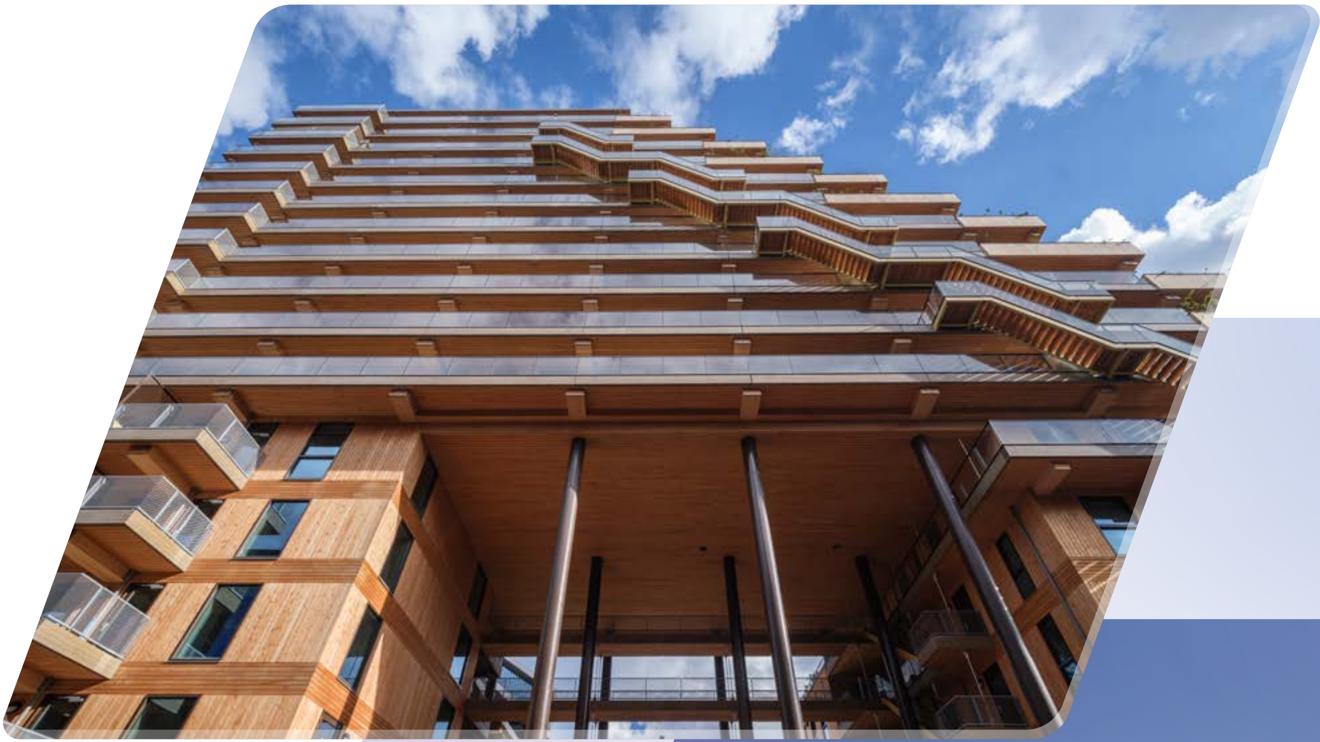
Photography: Benoit Diacre

## World of Volvo, Gothenburg, Sweden, 2023

- The World of Volvo in Gothenburg is Scandinavia's largest and most complex timber structure. Designed by Henning Larsen Architects, this multi-storey building, constructed from timber and glass and providing 22,000 m² of floor area, is a pioneering project that has taken sustainable timber construction to new dimensions

- The engineering and construction of the complex timber structure, spanning a diameter of 110 meters, were carried out by WIEHAG Timber Construction from Altheim (AT). The supporting structure consists of precisely manufactured timber components, whose curved geometry was realized through digital planning and industrial prefabrication. The gigantic beams and columns made of glued laminated timber (glulam) were prefabricated at WIEHAG using computer-controlled manufacturing and transported to Gothenburg by special haulage. AkzoNobel products used include the Adhesive System 1247/2526 for glulam elements. WIEHAG also designed and dimensioned the steel connections and pre-assembled them at the factory. Concealed within the timber structure, these connections provide the necessary stability while preserving the building's sophisticated architectural expression





## SAWA building Rotterdam, the Netherlands, 2025

- The SAWA residential building in Rotterdam is the first high-rise building in Rotterdam constructed entirely from wood and designed to be dismantled, combining ecological responsibility with social innovation and being awarded the best building in the Netherlands

- The DERIX-Group, one of Europe's leading engineered timber construction companies, was responsible for the planning and production of the load-bearing timber components. Various products from the DERIX-Group were used in the construction of the building, including cross-laminated-timber (X-Lam) and glued laminated timber (glulam).

  In the production of the glued laminated timber, AkzoNobel's GripPro® Nature A011-B50 adhesive was used. This is a non-classified melamine adhesive with a formaldehyde content like that found naturally in wood. This adhesive was also produced in a more sustainable process using bio-methanol

- Other companies involved:
  – Architect: Mei Architects
  – Structural Engineering: Pirming Jung Deutschland GmbH
  – Developer: Nice Developers & ERA Contour

Photography: Ossip van Duivenbode

## Rijksmuseum, Amsterdam, the Netherlands, 2003-2013

- The monumental Rijksmuseum building was renovated between 2003 and 2013 with some of the interior areas such as the Gallery of Honor and the complete exterior building elements being repainted with Sikkens products. Sikkens Rubbol XD lacquer was used on the exterior wooden windows, benefiting from a seven-year guarantee and extending the paint maintenance cycle compared with other paints that require a five-year repainting cycle for this type of historical wooden window frame. The seven-year guarantee is specific for this type of historical wooden window frame. The service life of the Sikkens Rubbol XD for modern wooden window frames is up to ten years

- Other companies involved:
  – Architects: Cruz y Ortiz Arquitectos, Wilmotte & Associés, Van Hoogevest Architecten
  – Painting companies: Van Vonderen, Hoogstraten Haarzuilens BV


Photography: David Lichtneker

07

# Conclusion and next steps

The drive to reduce embodied carbon in buildings requires us to take a fresh look at the materials we use and the ways we protect them. The comparative lifecycle assessment described in this white paper shows that, in typical façade and window applications, timber-based systems have lower carbon footprints over their typical lifecycles than aluminum, steel and PVC alternatives, even when using conservative assumptions and including realistic coating maintenance.

It also shows that the choice of substrate is the primary driver of carbon emissions. Coatings, while not insignificant, are a smaller part of the picture. Crucially, high quality coatings play a positive role in sustainability by protecting timber and extending its service life. Their value lies not in minimizing their own carbon emissions, but in how effectively they preserve the performance and longevity of the substrate.

Beyond carbon, wood contributes to healthier, more comfortable and more visually engaging buildings. Engineered timber products, combined with modern adhesives, coatings and fire protection systems, enable timber to be used safely and durably in a wide range of applications, from façades and windows to structural systems and interiors.

For architects, engineers, developers and manufacturers, the message is clear: wood deserves serious consideration as a primary material when designing for low embodied carbon, high quality environments. The key is to specify it carefully and protect it thoughtfully, so it can deliver both lasting performance and long-term carbon benefits.

AkzoNobel is ready to support this shift. With detailed PCF product data, a broad portfolio of industrial wood coatings, wood adhesives and decorative paints, and deep experience across substrates.

**AkzoNobel can:**

- **Help compare material and coating options based on their lifecycle carbon footprints**
- **Recommend coating systems and maintenance strategies suited to specific climates and applications**
- **Provide product warranties and performance guarantees where applicable**
- **Support the integration of coatings into lifecycle assessments and green building certification programs**
- **Collaborate on pilot projects and case studies that demonstrate the practical benefits of timber solutions**
- **Offer a unique solution combining industrial applied wood coatings with decorative paints for maintenance, providing one optimized solution throughout the building's lifetime**

To learn more about the lifecycle assessment, discuss project specific questions or explore potential case studies, stakeholders are invited to contact their local AkzoNobel representative or visit the company's website (Green buildings | AkzoNobel).

# References


[1] Study from Metten, Valon (UvA, 2025). Climate impact of coated objects from cradle-to-grave [Master's thesis, University of Amsterdam & Vrije Universiteit Amsterdam].

[2] UNEP & Global Alliance for Buildings and Construction (GlobalABC), Global Status Report for Buildings and Construction (2024/2025). The buildings and construction sector accounts for around 37% of energy and process-related $CO_2$ emissions globally. Not just another brick in the wall: The solutions exist – Scaling them will build on progress and cut emissions fast. Global Status Report for Buildings and Construction 2024/2025

[3] International Energy Agency (IEA), Buildings (Energy System tracker), https://www.iea.org/energy-system/buildings. Building sector energy intensity per m² has fallen roughly 6–8% since 2015, with operational emissions per m² declining in several advanced economies. Buildings – Energy System – IEA

[4] UNEP & Global Alliance for Buildings and Construction and Yale: Lifecycle thinking, decarbonization requires a whole lifecycle approach 2.1 Embodied versus operational carbon emissions in buildings

[5] World Green Building Council, Bringing Embodied Carbon Upfront: Coordinated action for the building and construction sector to tackle embodied carbon (2019). Bringing Embodied Carbon Upfront – World Green Building Council

[6] Buildings and Climate Global Forum – Declaration de Chaillot

[7] Directive (EU) 2024/1275 (recast Energy Performance of Buildings Directive). Lifecycle global warming potential must be calculated and disclosed for new buildings over 1,000 m² from 2028 and for all new buildings from 2030; Member states must publish roadmaps introducing GWP limit values by 2027

[8] See the rating-system documentation: U.S. Green Building Council, LEED v4.1 (Materials and Resources credits); BRE, BREEAM (Mat 01 lifecycle impacts); and DGNB System criteria on lifecycle assessment and sustainable material sourcing. New LEEDv5 Requirements Align with PEFC and SFI - PEFC - Programme for the Endorsement of Forest Certification

[9] Arup, Improving Whole-Life Carbon Estimates for Buildings Constructed out of Timber, prepared for the UK Department for Environment, Food & Rural Affairs (DEFRA) (2025). See also G. Churkina et al., "Buildings as a global carbon sink," Nature Sustainability 3 (2020), 269–276. improving-whole-life-carbon-for-timber-buildings.pdf

[10] See, e.g., A. Q. Nyrud & T. Bringslimark, "Is Interior Wood Use Psychologically Beneficial? A Review of Psychological Responses Toward Wood," Wood and Fiber Science 42(2) (2010), 202–218 (View of Is Interior Wood use Psychologically Beneficial? A Review of Psychological Responses Toward Wood)

[11] D. R. Fell, Wood in the Human Environment: Restorative Properties of Wood in the Built Indoor Environment (PhD thesis, University of British Columbia, 2010) (Wood in the human environment: restorative properties of wood in the built indoor environment - UBC Library Open Collections)

[12] G. Lowe, Wood, Well-being and Performance: The Human and Organizational Benefits of Wood Buildings (2020) (Report: Wood, Well-being and Performance: The Human and Organizational Benefits of Wood Buildings)

[13] See, e.g., W. D. Browning, C. O. Ryan & J. O. Clancy, 14 Patterns of Biophilic Design (Terrapin Bright Green, 2014) (14 Patterns of Biophilic Design) ; and R. S. Ulrich, "View through a window may influence recovery from surgery," Science 224 (1984), 420–421. (View through a window may influence recovery from surgery – PubMed)

[14] Cross-laminated timber (CLT): structural panels made of layers of solid timber glued at right angles for two-way strength. Glue-laminated timber (glulam): structural beams and columns formed by bonding timber laminations along their length.

[15] The future is wood: innovation in timber construction | Research highlights | Forest Information System of Europe; Hana Svatoš-Ražnjević, Yana Boeva, Cordula Kropp & Achim Menges (June 10, 2025): Trajectories from standard to incremental and pioneering innovation in timber construction: multi-storey timber buildings in Germany, Austria, and Switzerland, Building Research & Information, DOI:0.1080/09613218.2025.2482970 [link]

[16] What is the thermal conductivity of wood and how does it compare to other materials? – American Wood Council