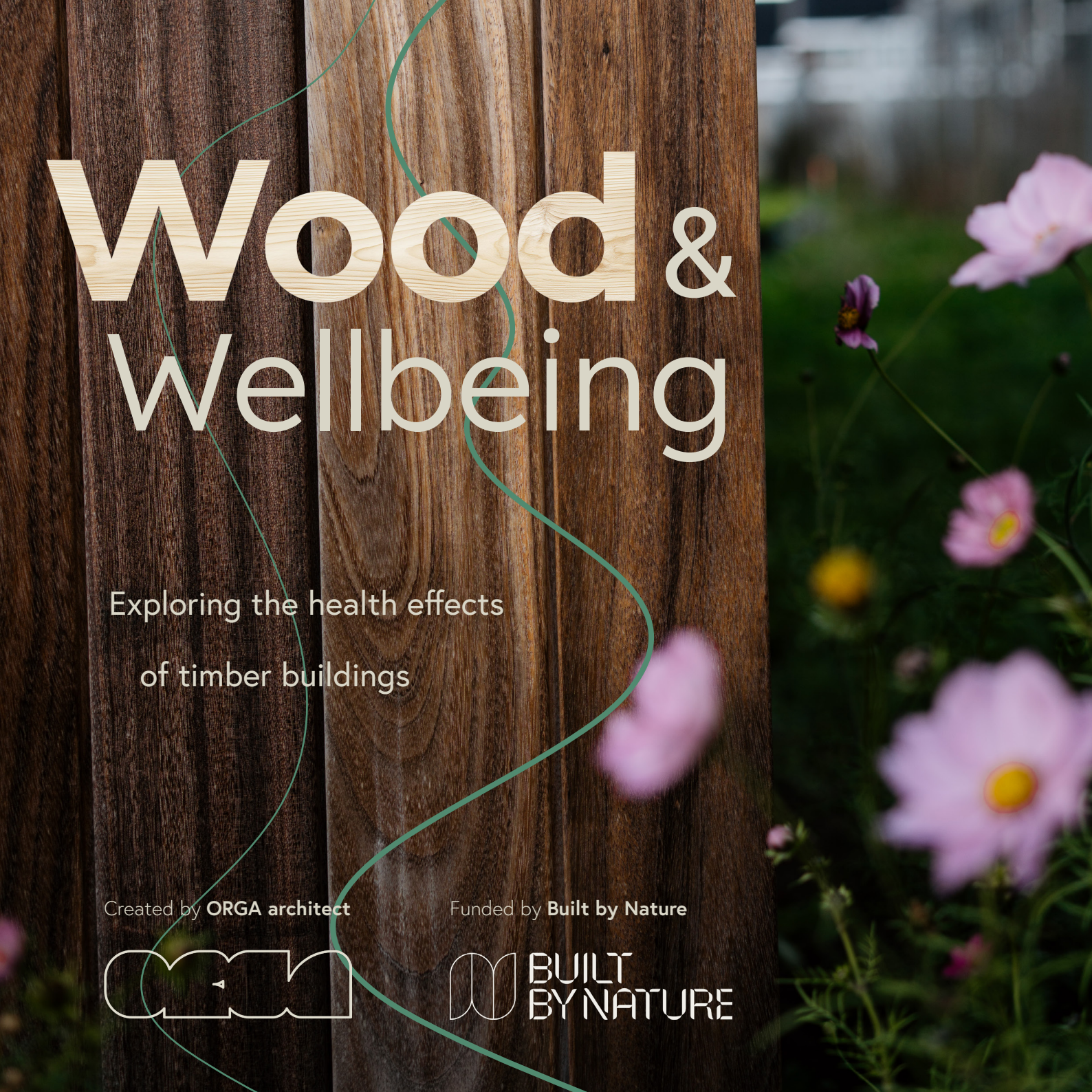


Wood & Wellbeing

Exploring the health effects of timber buildings

Created by **ORGA architect**

Funded by **Built by Nature**

BUILT BY NATURE

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*Wildlife shelter **Avolare** by ORGA architect*

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Executive summary

For most of human history, the choice to build with timber was instinctive and drawn from what the natural world offered. Today, scientific findings on health and wellbeing benefits are giving us new reasons to make that same choice.

This document brings together evidence from peer-reviewed research, industry reports, and white papers to explore how timber buildings affect the health of people who live and work in them. A basic framework was developed that places these findings in two broad categories: the physical properties of wood as a material, and the way the human mind and body respond to the presence of wood.

On the material side, several qualities of timber distinguish it from conventional alternatives. It has the capacity to insulate and store heat, helping to maintain stable indoor temperatures without heavy reliance on mechanical systems. Exposed wood surfaces naturally regulate indoor humidity by absorbing and releasing moisture, keeping air quality within a comfortable range. And the surface chemistry of wood gives it antimicrobial properties, with research showing that wooden surfaces outperform plastic and steel in resisting the survival and spread of bacteria and viruses.

However, working with timber is not completely without limitations. For instance, timber structure and prefab elements always need to be protected from rain at the building site. Engineered wood products bonded with formaldehyde-based adhesives can compromise indoor air quality, making careful product selection essential to creating healthy buildings. And designers and engineers need a certain amount of knowledge and experience to get the most benefit out of having wooden surfaces in spaces.

The evidence of positive effects to mental health side is equally compelling. Studies using biometrics and brain imaging consistently show that the visible presence of wood reduces physiological stress, lowers blood pressure, and promotes recovery of focused attention.
People in wooden spaces feel calmer, sleep better, concentrate more effectively, and report higher levels of wellbeing. All these effects appear to be rooted not in personal preference, but in a shared human biology shaped by hundreds of thousands of years of evolution in natural environments.

These findings have direct and practical consequences for the organisations that commission, fund, and design buildings. Health-focused buildings command measurable premiums in both residential and commercial real estate. Natural workspaces improve productivity, creativity, and staff retention. In short, timber construction addresses all three pillars of ESG reporting in ways that can be documented and verified.

Individual studies in this field acknowledge their limitations, and the full picture is still being assembled. But the breadth and consistency of the evidence points clearly in one direction. Built well and designed thoughtfully — with exposed wood surfaces, breathable finishes, and complementary natural materials — timber buildings are healthy buildings.

About the authors



Gijs Bruggink, M.A., has spent the past decade and a half working at the frontier of what responsible, nature-connected architecture can be. As studio manager and researcher at ORGA architect, a Dutch architecture firm at the cutting edge of biobased innovation, he has built and maintained the operational backbone of a growing, internationally active practice, while carving out a parallel career as a consultant and researcher in the regenerative built environment.



Ralf van Tongeren, M.Arch, is an innovator, a senior architect at ORGA, and a passionate advocate for biobased materials like hemp and straw. He combines his deep technical knowledge of building physics with a simple mission: creating healthy, natural living spaces that benefit both people and the planet through sustainable, regenerative design.



Daan Bruggink, M.Arch, is the founder and lead architect at ORGA. By merging advanced ecological principles with modern design, he creates high-performance, nature inspired, and low impact buildings. His work redefines the relationship between people and nature, positioning him as a primary architect of the circular economy and the next generation of sustainability.

How-to-use

Wood and wellbeing is a complex and expansive subject and as a consequence, this publication contains tons of information. To accommodate different interests and the varying amounts of time that readers have available, the report offers several levels of reading.

Main narrative

Read about the main topics and findings without taking in all the research and case studies.

Recaps

When time is limited, scan the green content blocks to get a quick overview without all the context.

Studies and cases

Understand the research methods to get a fuller grasp of all the findings. That's where the beige content blocks come in.

Over the past decades, pioneering timber architects and builders have already put much into practice. Some of their work is presented in the beige blocks.

Deep dives

Dig deeper with the dark gray content blocks which offer additional chunks of background knowledge, often of a more technical nature.

Relevant, but not required for a good understanding of the different ways in which timber buildings make healthy buildings.

Introduction

The practice of using wood as a building material is as old as civilisation itself. Wood crafting originated in ancient times when humans lived in close connection to nature and started adapting directly available materials to create tools, build shelters and live in settlements.

Only in recent centuries have we started to focus on functionality, economic growth, and technological advancement, during which time the building industry shifted to fossil fuel-based materials. Using these finite resources, building design has reached incredible levels of efficiency and technical performance, as showcased in our urban environments. Here, millions of people gather to live and work in concrete, steel and glass structures that soar hundreds of meters towards the sky.

However, these conventional building methods came to use in an age when the world was not yet feeling the pressure of climate change. The effects of the built environment on human health were not well documented. Maintaining this narrow focus on economics alone simply does not do justice to the realities of the 21st century. Society today desperately seeks to reduce the negative impact we have on the planet and to prevent modern-day ailments such as burn-out, depression, and sick building syndrome.

This current state of affairs demands a renewed evaluation of the way we look at the built environment and the materials we use to create it. As old as the use of wood as a building material might be, we are still learning new things about its potential benefits.



A word from the authors

A growing body of research is exploring how timber can be used to create healthy buildings and restorative environments for us to live and work in. For a while now, experts all over the world have been discussing how building with timber can lower negative impacts on the planet through emissions reduction and carbon storage. With this report, we aim to add the dimension of human health to the dialogue.

Based on a 100+ recent peer-reviewed articles, research studies, white papers and industry briefings, this report provides an evidence-based overview of the health effects of building with timber and integrating wooden surfaces in spaces.

Our main goal is to build a bridge between scientific research and the actual creation of buildings. We aim to do this by informing professionals and organisations that are in a position to directly implement a more climate-aware and healthier building practice.

Many of the studies, experiments and surveys that were reviewed recommended further research at a larger scale and with a broader scope. But as one reads through the sheer amount and variety of evidence, the strength of their combined argument cannot be denied: wooden buildings create healthy environments.

We hope this report offers you both the insight and the inspiration to make that case in your own work.

Gijs, Ralf & Daan
ORGA architect



***Forest House** in Maarn (NL) by ORGA architect*

Methodology

The findings in the report originate from a large collection of publications by scientific and industry experts. These include peer-reviewed academic literature and review articles, trade publications, white papers, and online resources. The data includes both ‘hard’, quantifiable metrics and results of a ‘softer’, qualitative nature that were collected through surveys and questionnaires.

Methods for finding source material include keyphrase searches through Google Scholar, author and topical searches using AI-assisted search tool Elicit and tracking citations in recent reports and literature reviews. With the exception of a few highly relevant older publications all research articles and reports date from the years 2000 to 2026. For industry reports and white papers providing information on market trends and developments in the building industry we have used a more narrow timeframe of 2020 to present. A complete annotated list of source material can be found in the back of the document.

Though its creation was supported by AI-assisted tools, the report is entirely written and edited by human hands. No generative AI has been used to directly create any of its contents. Claude AI and NotebookLM were used under strict instructions for the purpose of analysing source material, never without a human verifying their output. During the editing process, Claude AI and Gemini provided suggestions for improving spelling and grammar.

Every effort has been made to correctly credit the copyright holders of images used in this publication. Anyone who believes their work has not been properly attributed is warmly invited to get in touch with the authors, so that any omissions can be corrected.



*Artist Katie Paterson and architects Zeller & Moye gathered 10,000 unique wood species from every country on the planet to create the artwork ‘**Hollow**’: a forest of all the world’s trees in microcosm, spanning millions of years. The pavilion was commissioned by the University of Bristol (UK) and is located at Royal Fort Gardens.*

Health effects framework

When exploring the link between the materials in a building and the health of its occupants, it soon becomes clear that these effects stem from a continuous and complex interaction between the human body and its environment. A deeper understanding of this interaction requires insights from many fields of knowledge, ranging from design and engineering to medicine and the social sciences. In order to organise all these insights and provide structure to the report, a basic framework was developed.

The purpose of the framework is to present an overview of all the types of health effects that take place when people come into contact with wood in the spaces where they live and work. The model is not intended to introduce a hierarchy among the different health effects or weigh the strength of their impact.

While not suitable to be measured directly, surveys and questionnaires can provide valuable insight into people's experience. In addition, medical science increasingly understands how the human body responds to stressful or relaxing conditions and these responses can be monitored, providing a way of indirectly measuring the way we experience spaces.

Recent decades have seen a rise in mental health issues. In response, science has started to look into ways to improve the built environment as a preventive measure. Cross-disciplinary fields such as environmental psychology, biophilic design and neuro-architecture are dedicated to exploring how the built environment affects the mind.

The framework not only offers a compact overview but also forms the backbone of the narrative. Different segments of health effects will be discussed in separate chapters throughout the report, beginning with the material properties and followed by the psycho-physiological effects.

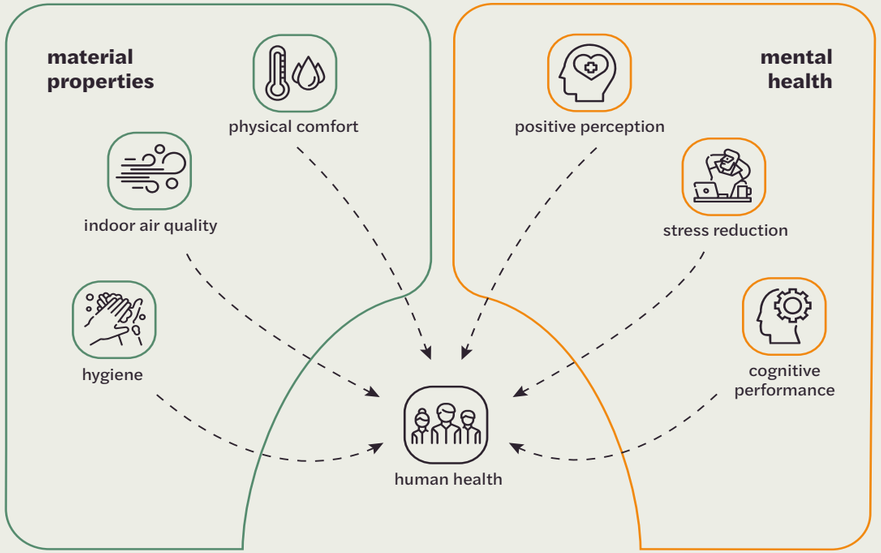
The third section presents how these health effects have real consequences for stakeholder groups in the building industry, by discussing a shift in consumer preferences, building certifications and improvements to the workplace.

Government organisations and policymakers are presented with steps they could take to promote public health by facilitating timber construction and supporting research.

Architects and engineers can find both insights and guidelines on how to achieve the greatest health outcomes from working with timber materials.

What is health?

Italian psychologist Fabio Leonardi states that definition of health should have at least 9 features to work well.[1] Health should not be reduced to diseases or infirmities, nor to physical parameters. It is constructed as a capability to be healthy, which is an ongoing process, potentially achievable for everyone, in all circumstances. It includes both malaise and well-being, avoiding the risk of being utopian. In short, health is the capability to react to all kinds of environmental events having the desired emotional, cognitive, and behavioral responses and avoiding those undesirable ones.



The left side of the framework deals with the direct effects of wood's material properties on the interior environment. Many of these aspects can be expressed in hard numbers and lend themselves to being measured through sensors, instruments or laboratory testing. As these health effects are suitable to be quantified into objective data, a considerable body of research has been established over the past few decades.

The right side of the framework addresses the psycho-physiological responses people have to the visual, tactile or olfactory presence of wood in their surroundings. These effects work on the level of perception and experience and can differ from person to person. These types of benefits have a 'softer' and more subjective nature, but they can nonetheless have a powerful influence on wellbeing.

1 Material properties

Millions of years of 'research and development' through the process of evolution have led to natural materials such as timber with the inherent ability to adapt to the conditions around them. The level of comfort and wellbeing that humans experience in wooden spaces is directly related to this ability to deal with changes in temperature and humidity or the resistance to harmful microbes.

This section of the report examines four ways in which timber's material properties influence the indoor environment: the role of thermal mass and insulation in maintaining temperature comfort, wood's hygroscopic capacity to passively regulate indoor humidity, the dual nature of volatile organic compounds in timber buildings, and the emerging evidence on wooden surfaces and hygiene.

***Timber House** in Harmelen (NL) by ORGA architect*

The components of thermal comfort

When looking at ways to maintain a comfortable temperature inside a building, thoughts usually jump straight to the choice of insulation or air conditioning system. This does make sense, but it also ignores a second component that is becoming increasingly relevant with global temperatures rising: thermal mass. This section examines these two components of thermal comfort and how timber performs on this front.

Historically, buildings were often constructed using a single, thick material. Consider a rugged log cabin, for example, or a solid stone house. Over time, advances in energy efficiency dramatically changed how we build and today our walls are constructed in layers, much like a sandwich, where every layer has a specific part to play.

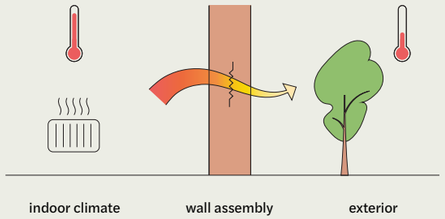
The insulation layer's primary role is to act like a winter coat for the house and trap heat inside, especially in colder climates. In hotter climates, which cover an ever-growing part of the planet's surface, this strategy changes completely. There, the goal is to keep the heat out. For that reason, the most effective buildings in warmer regions often consist of materials that can store heat, a property known as thermal mass. Understanding how both insulation and thermal mass can work in tandem is key to our comfort and wellbeing.



Close up during construction of a timber frame wall with wood fibre insulation

The insulation component

Nature always moves towards balance and tries to maintain it. This principle also applies to heat. Heat is energy and basic rules of physics state that it always flows from an area with more energy (hot) to an area with less energy (cold), until the two equalise. To stay warm during the cold months in the northern hemisphere, a layer of insulation is included in buildings to prevent heat loss by significantly slowing down the flow of thermal energy from the warm indoors to the cold outdoors.



Wall insulation prevents heat loss

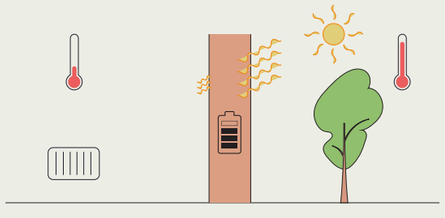
The thermal mass component

When visiting a historic city in the summer, have you ever noticed how an old stone castle or church feels surprisingly cool inside? That is thermal mass at work. The castle's massive walls of dense stone act as a battery for thermal energy. They absorb the sun's energy during the day, gradually storing it within the stone itself. Because the heat is being stored and not heating up the air inside, the interior space stays comfortably cool.

At night when the outside air temperature drops, the process reverses. The walls slowly release all the heat they stored during the day, thereby helping to keep the interior space comfortably warm. This delaying effect on thermal energy that evens out the changes in environmental temperature is often called 'thermal lag'.

Thermal mass is mostly a product of a material's density. Heavy, dense materials like stone, concrete, or brick have high thermal mass and as a result they can store a lot of heat. Lighter materials, such as the popular insulation materials mineral wool and glass fibre wool, are much less dense and cannot store nearly as much.

To sum things up: the two components perform different but complementary jobs to provide thermal comfort for a building. Insulation functions like a barrier that stops heat from moving from one side of a wall or roof to the other. Thermal mass works like a buffer that absorbs and stores heat for a while and then releases it.



Thermal mass delays heating or cooling effect



***Forest House** in Maarn (NL) by ORGA architect*

Insulation value standards

Insulation is an expression of the thickness (**d**) of a material and a property known as the Lambda-value (**λ**) or K-value, which measures thermal conductivity. A very low **λ**-value means the material is a poor conductor of heat, which is exactly what you need from insulation.

To express the level of insulation, two main values are used:

- **R-value** (thermal resistance): This measures how well an insulation material resists the flow of heat. Think of it like the thickness of a winter coat. A high R-value means very little heat is flowing through. This is calculated by dividing the thickness by the Lambda-value: **$R = d/\lambda$**
- **U-value** (thermal transmittance): This measures how much heat passes through a material or a whole building assembly (like a complete wall or window). A low U-value means very little heat is escaping. This is calculated by inversing the R-value: **$U = 1/R_{total}$**

Timber construction methods

Nature-based buildings usually feature a timber frame structure in combination with layers of plant-based insulating materials and finishes. A popular and centuries-old approach is to erect a structural frame of timber posts and beams and then add layered walls and roofs, including layers of natural insulation.

Nowadays, timber frame structures often use solid wood beams or beams that consist of multiple laminated layers of wood, such as glulam or Laminated Veneer Lumber (LVL). To add stability and rigidity to the timber frame structure, builders usually add high-density particleboard.

A rapidly emerging alternative, especially for mid- to high-rise buildings, is using mass timber panels that act as load-carrying walls, with layers of insulation and finishing applied on the vertical surface.

For example Cross-Laminated Timber (CLT) which gains strength from cross-layering the wood grain or Dowel-Laminated Timber (DLT), which forgoes adhesives in favour of wooden dowels. These contemporary variations have the advantage of providing both insulation and a decent amount of thermal mass.

When combined correctly, they demonstrate a remarkable all-round performance as a whole — good at resisting heat, but also at absorbing and storing it. This proven combination keeps a building comfortable without having to rely heavily on HVAC systems (Heating, Ventilation, and Air Conditioning systems). In these times of rising energy costs, this is a notable advantage over the conventional building systems that currently dominate the global building industry.

Industry standards for thermal comfort

True thermal comfort is about more than just the number on the thermostat. It is the result of a smart, integrated design where many factors work together. The main industry standard for comfort, ASHRAE Standard 55[2], identifies six key factors that all play a role:

- **Air Temperature**: This is what the thermostat reads.
- **Radiant Temperature**: The heat you feel radiating from surfaces.
- **Air Speed**: A slight breeze or a draft.
- **Humidity**: The amount of moisture in the air.
- **Clothing**: The insulation one is wearing.
- **Metabolic Rate**: The heat your own body is producing through activity.

Other standards on thermal comfort, such as ISO 7730[3] (International) or EN 16798-1[4] (European), offer a similar approach. In most cases, these standards are built on the very same scientific principles pioneered and codified by ASHRAE.

*Construction of the **Wiltensacker** country house in Epe (NL) , executed in timber frame construction with glulam beams and columns.*

Lightweight vs heavy weight

In the early 1980s, it was debated whether solid wood walls met insulation standards, as the standard insulation value (R-value) did not account for thermal lag. The 'NBS Log Home Study', an influential research report in building physics, demonstrated that the thermal mass of wood absorbed temperature peaks during the day and released them gradually at night, significantly reducing how often the thermostat needed to engage.[5]

Since then, renowned institutes such as the Fraunhofer Institute for Building Physics (IBP) in Germany and the Building Research Establishment (BRE) in the UK have investigated thermal mass in various biobased materials, including solid wood, straw and hempcrete. These studies consistently show that biobased materials have a profound effect on smoothing out temperature peaks by utilising their thermal mass.



A small crane hoists EcoCocon® prefabricated panels in place. Made of 98% natural renewable materials, these panels combine the material properties of timber, compressed straw and clay to provide indoor comfort.

Thermal lag

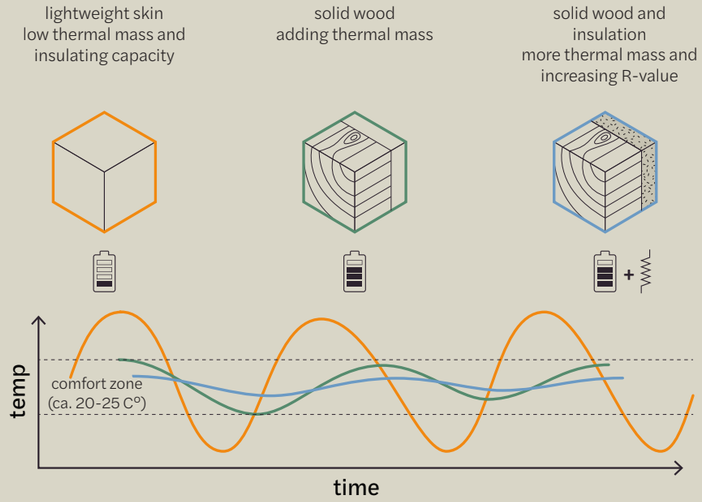
The heat performance of several wall types was put to the test in a 2022 study in the US.[6] The comparison included two types of lightweight timber frame walls with mineral wool insulation and two types of mass timber walls. Full scale laboratory tests of wall assemblies and advanced computer simulations were combined to establish solid data for a complete building model.

The mass timber walls showed a significant improvement in thermal comfort, leading to a 31–46% reduction in hours of uncomfortable temperature levels per day. Adding a layer of insulation improved thermal comfort even further, with an additional 19–32% reduction in discomfort.

The researchers concluded that indoor temperature moderation was a result of the mass timber wall assemblies' ability to delay thermal changes and balance heat flows.

The timber walls stored and released heat, dampening temperature fluctuations and keeping them at human comfort levels longer. They noted that these effects are even more pronounced in climates with significant daily temperature variations.

The key takeaway here is that the lightweight walls were insufficient in mitigating overheating. While mineral wool is an excellent insulator, it has almost no thermal mass, which means it does little to prevent a room from overheating on a sunny afternoon. By designing for thermal lag — when insulation and thermal mass are balanced — temperature fluctuations can be more effectively moderated for optimal indoor comfort and wellbeing.



The higher thermal mass of the timber wall assemblies helps keeping the indoor temperature within human comfort levels. Based on Salonvaara et al. - 2022.[6]

Installation-free buildings

The core design principle behind **Building 2226** in Lustenau (AT) by Baumschlager Eberle Architekten was simple: maintaining comfort without mechanical heating, ventilation, and cooling systems. With the people, the lighting, and the office equipment as the only heat sources, the challenge lies in retaining that warmth year-round.

By utilising the thermal mass of 70-cm brick walls the office building can naturally stabilise the indoor temperature between 22° C and 26° C. Together with automated CO2 controlled ventilation, these fundamental natural principles create a balanced, comfortable and inviting workspace no matter the season.



OZ architect was inspired by the concept of Building 2226 for the design of their new offices in Amsterdam (NL). The low-tech **ONO** building combines biobased materials, passive building techniques and a similar natural ventilation system to the Austrian design.

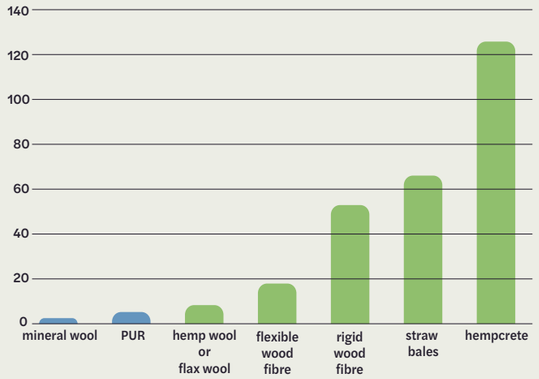
Thick wall assemblies consist of mass timber, prefab hempcrete blocks, and lime plaster. In combination with adobe block walls and added mass in the floors, these provide sufficient thermal mass to eliminate installations for cooling and heating. Natural ventilation, as in Building 2226, is controlled by intelligent software that operates movable window panels to regulate indoor comfort levels.



Natural insulation

Just as mass timber performance can be upgraded by adding insulation, the thermal performance of timber frame structures can also be greatly improved when sensible choices are made regarding the type of insulation material that is applied.

Natural wool insulation significantly outperforms mineral wool or poly-urethane foam panels in heat retention. In addition, timber frame wall assemblies based on wood fibre boards, strawbales or hempcrete can exponentially improve heat retention, as the study on the right demonstrates.



Thermal capacity (KJ/m²K) measures how much heat a material can store. Biobased insulation materials (green) consistently outperform conventional alternatives (blue) on this front.

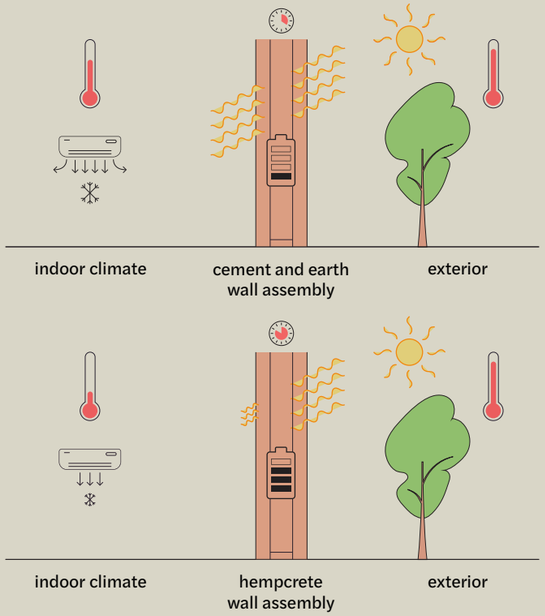


*The pavilion at **Nature Cemetery Slangenburg** in Doetinchem (NL) by Giesen Architectuur is used for hosting farewell ceremonies and memorial services. The walls were created by pouring hempcrete around a timber frame on-site using formwork, providing a considerable amount of thermal mass. The striking layered textures were achieved by adding natural pigments to the hempcrete layer by layer.*

Materials compared

A 2024 Canadian study compared the performance of cement blocks, compressed earth, and hempcrete, which is a hempfibre and lime-based bio-composite.[7] Using dynamic simulations that exposed the different wall types to solar heat the researchers found that careful material selection is critical for ensuring optimal performance.

The interior temperatures of the cement and earthen wall assemblies fluctuated significantly and reached extremes up to 27°-29°C, while the hempcrete walls maintained a comfortable 22°C to 24°C. Even with a 20% increase in solar heat, the temperature in the hempcrete wall only increased 0.12°C. In short, the hempcrete acted as both insulation and thermal mass, effectively eliminating the need for air conditioning in this scenario.



Timber frame walls with low thermal mass (above) versus high thermal mass biobased insulation (below).

Project **Einfach Bauen** (Building Simple) is a direct response to the increasing technification of the construction industry. This design collaboration at the Technical University of Munich led by architect Florian Nagler Architekten and climate expert Thomas Auer explores achieving perfect comfort through material intelligence alone.

The team followed a rigorous ruleset in order to reduce complexity:

- **Monolithic Walls**: No ‘sandwiches’ of different materials, foams, or foils. The all-in-one wall offers structure, insulation, and finishing.
- **Thermal Mass**: Thick walls that store heat and cold to keep the indoor climate stable.
- **No Complex Tech**: No mechanical ventilation or automated shading, just openable windows.
- **Longevity**: Buildings designed to last 100 years.

Three identical apartment buildings were constructed, each using a single material: mass timber, masonry, and lightweight concrete. Two years of monitoring showed that the buildings provided excellent thermal comfort for the occupants, as the walls effectively buffered outside temperature swings.

The timber building in particular, demonstrated exceptional summer performance, preventing overheating without any active cooling. Additionally, it outperformed the other materials in moisture regulation. Measurements showed that the natural material maintains a stable and comfortable humidity level between 40% and 60%.



→ **Recap** Thermal comfort

- Thermal comfort depends on two properties working together: **insulation**, which slows heat movement, and **thermal mass**, which stores and releases it. Currently, most buildings only optimise for the first.
- **Timber wall assemblies** can deliver both — either as mass timber, or as a timber frame paired with natural insulation. These slow heat transfer like conventional insulation, and also smooth out fluctuations in outdoor temperatures.
- **Biobased insulation** — woodfibre, straw, hemp — outperforms mineral wool because it both insulates and stores heat.
- Buildings built from natural materials alone can provide **indoor comfort year-round**, reducing or even removing reliance on mechanical heating or cooling.

Most building codes still focus on insulation values and barely take the effects of thermal mass into consideration, which has led to many buildings being designed without taking full advantage of timber’s natural comfort benefits.

Balancing moisture and humidity

Proper control of moisture is essential for both the structural integrity of buildings and the health of the occupants. When left unchecked, excess moisture can cause serious damage to the structure and interior of a building. With a solid understanding of its properties, timber can be a reliable tool in managing humidity.

Preventive measures

Wet or humid areas in walls or roofs can begin to weaken through rot or become a breeding ground for mould, which in turn can compromise the indoor air quality and occupant health. Avoiding these moisture-related issues in buildings starts with preventing the moisture from being there in the first place, such as from poor quality construction or from building components being overexposed to rain at the building site before installation.

Despite timber components being especially vulnerable to moisture, builders sometimes handle these components exactly the same as they would concrete, steel or plastic. As a result, soaked or partially wet wall or roof elements end up in the structure without getting the chance to dry out first. Excess moisture that lingers can eventually penetrate into the interior and affect occupants' health.

Issues resulting from careless handling of timber components should not be underestimated. Without proper precautions, mould and wood rot can easily take hold as soon as the building is completed.

Fortunately, material handling and storage practices can be improved with proper instruction and moisture damage from rain exposure will likely occur less as the ongoing transition to natural building materials progresses. Timber building elements are increasingly pre-fabricated under more protected conditions and improved on-site practices, such as rainproof and ventilated storage for timber components, help keep the construction process as dry as possible.



Timber frame construction of the Wiltensacker country house. When rain exposure is unavoidable, including a drying period and monitoring moisture levels by taking measurements can prevent issues in the long term.

Taking moisture readings at the building site is one way to prevent damage. The timber knowledge base Centrum Hout (Woodcentre) in the Netherlands published maximum moisture content ratios for timber components, for instance, 18–20% for structural framing and beams.[8] In general, timber builders apply a simple rule of thumb ratio: max 10% for interior woodwork, 13% for window frames, and 18% for general construction.

Even when a timber building is constructed under optimal conditions, the build-up of moisture or excessive humidity can still occur. Over a building's lifespan, incidents such as a leaky gutter or an overflowing bathtub can lead to moisture entering walls or roofs. Plus, there is the daily use by the occupants.

The Dutch Department of Health has stated that an average household produces 10-15 litres of moisture per day.[9] Well-known sources of elevated indoor humidity, regardless of building materials used, are cooking, showering, laundry routines, and human breath and perspiration. Moisture issues during the occupancy phase are often the result of insufficient ventilation or wall and roof assemblies that are unable to handle the humidity from daily use in the long term.

Wood Species	Application	Ideal Moisture %	Risks
Spruce	Construction (framing/roofs)	**18%**	Mould growth (at > 20%)
Pine	Facades / Garden use	**16-18%**	Resin bleeding and shrinking (when dry)
Douglas Fir	Outdoor structures (canopies)	**18-20%**	Warping and cracking (when dry)
Meranti	Window frames	**12-14%**	Jamming windows from swelling or shrinking
Oak	Flooring / Furniture	**9-11%**	Swelling or shrinking

Based on Dutch guidelines from Centrum Hout and NEN 5466[10] regarding equilibrium moisture content.

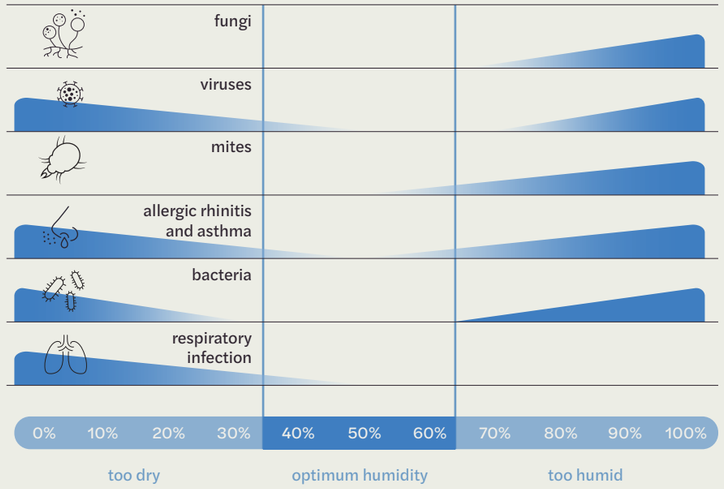
The right balance

An indoor climate that is either too dry or too humid can affect occupant health in a variety of ways. Relative Humidity (RH) is the key metric used to describe moisture conditions in indoor spaces. This refers to how much water vapour is present in the air as a percentage of the maximum amount the air could hold at a given temperature.

The Sterling-Arundel-Sterling chart below visualises a comprehensive review of medical, biological, and chemical data to determine the optimal RH levels for human occupancy.[11]

According to the data, a relative indoor humidity between 40% and 60% results in the fewest negative health effects. This optimal humidity zone is characterised by the following conditions:

- The air is humid enough to reduce the risks of airborne viruses, as respiratory droplets containing viruses absorb water, become heavier, and fall to the floor.
- The air is dry enough that dust mites and mould cannot reproduce effectively.
- There is enough moisture in the air to keep human skin and eyes hydrated and keep the mucous membranes in the airways intact.



Maintaining optimal relative humidity contributes to the prevention of a variety of health risks Based on Sterling et al. - 1985.[11]

In particular, buildings that experience prolonged periods high or low relative humidity, are at an increased risk of fostering negative health outcomes. Often, those who are affected struggle to identify the specific causes for their symptoms. Which is one of the reasons for the phrase 'sick building syndrome', coined at the end of the 20th century as a collective term for health complaints associated with poor-quality indoor environments.

Despite clear indications that maintaining an optimal RH is necessary for creating healthy spaces, few countries include it as a specific metric in their building regulations. The default solution proposed for ensuring proper indoor air quality is mechanical ventilation. In fact, most buildings that are currently considered highly sustainable fully rely on large-scale high-tech ventilation systems to maintain indoor air quality, at the cost of increasingly scarce fossil fuels, high embodied carbon levels and significant energy costs during operation.

As the pressure from climate change rises, solutions with considerable negative impact are no longer sustainable. The building industry has been exploring other methods to support or replace mechanical ventilation systems when it comes to regulating humidity levels. The previously under-valued capacity of natural materials such as timber to balance indoor humidity by buffering moisture has emerged as a promising low-impact alternative.

Moisture buffering explained

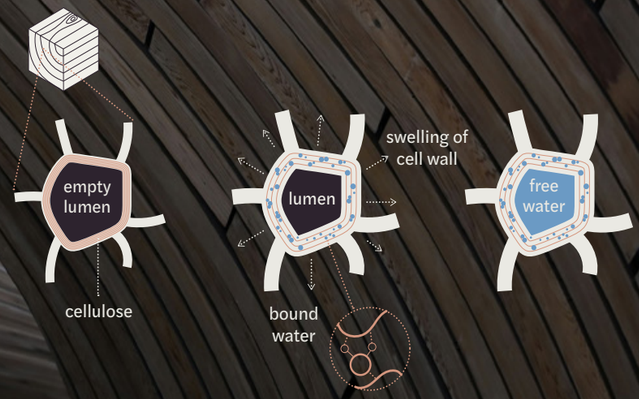
Like many plant-based materials, wood is **hygroscopic**: it has the capacity to absorb, store and release water vapour from the surrounding air. A proper understanding of the buffering effect in indoor spaces requires an examination of the way wood interacts with moisture on the microscopic level.

When wood contains moisture, that moisture exists in one of two states: as bound water or as free water. **Bound water** is moisture that is absorbed into the cell walls of the wood fibres themselves. This is comparable to a sponge that is damp to the touch; the material itself is wet, but when squeezed, no water drips out. In this state, it can only be released through a phase change known as desorption. It is this bound water that is directly linked to wood's hygroscopic behaviour and its ability to buffer indoor humidity levels.

Free water is moisture that sits in the open cavities inside wood cells called lumen. It is not absorbed into the cell walls, but simply present as liquid water in the voids of the material, much like water in the holes of a soaked sponge. In that state, it is not involved in the sorption exchange with the surrounding air. The boundary between these two states is described by the **Fibre Saturation Point** (FSP), which usually occurs around 30% moisture content, but varies by species. The hygroscopic properties of wood are influenced by those three aspects: bound water, free water and the FSP. With moisture content below the FSP, wood contains only bound water in its cell walls. It actively exchanges moisture with the surrounding air, functioning as an effective humidity buffer in indoor spaces. Above the FSP, the cell walls are fully saturated and any additional moisture exists as free water in the cell cavities. Now, hygroscopic activity diminishes and microbial colonisation becomes possible.

In order for building professionals to reach optimal health outcomes by using timber, it is of key importance to keep the material below the FSP, so it can continue to moderate indoor humidity and resist microbial colonisation effectively.

The moisture buffering activity of wood has a significant upside for comfort: it basically acts as passive climate control. By absorbing excess moisture when the room is damp and releasing it when the air is dry, wooden walls, floors, or furniture can help stabilise the relative humidity, smoothing out the peak fluctuations of the indoor climate. And it does so without the cost of fossil fuels, emissions, or energy.



Moisture buffering on the cellular level

Testing the buffering capacity

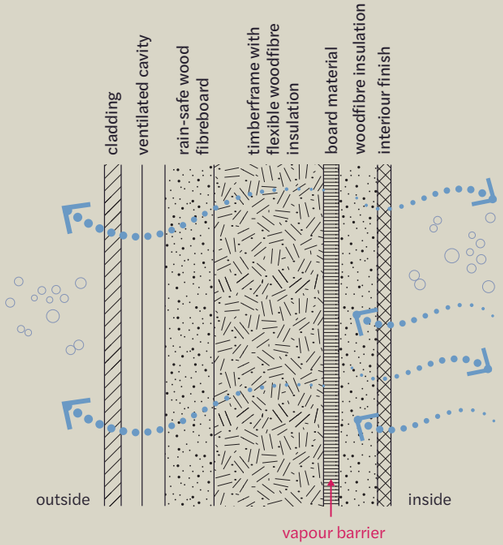
The Fraunhofer Institute for Building Physics (IBP) in Germany investigated the effects of moisture buffering for various interior finishing materials compared to standard interior plaster.[12] They found that several wood products significantly reduced the humidity fluctuations of indoor air:

- Untreated spruce wood panels reduced fluctuations by more than 50%.
- Scandinavian Pine Logs showed a reduction of 65–80% on the same surface area.
- Wood Fibreboard demonstrated the best short-term effect, reducing spikes in humidity by almost 80%.

The 2004 study also included a model with insulation material made from cellulose, which is derived from recycled paper. Again, they found a reduction compared to the control model with conventional insulation, though the amount of 15–30% was lower. As the insulation layer was not directly exposed to the air, the water vapour was stopped by the plasterboard layer, compromising the buffering capacity of the cellulose fibres.

This finding actually demonstrates one of the major takeaways from this report: optimal health outcomes require combining the natural properties of wood and other plant-based materials.

In this case, the IBP report offers valuable insight into how biobased materials function optimally in timber frame construction. A typical biobased wall assembly layers various moisture-buffering materials from the inside out, each layer a bit less vapour resistant than the previous one. This creates a vapour-open or 'breathing' building envelope that allows moisture to be transported and released to the indoor or outdoor air. As a result, the relative humidity indoors is maintained with the optimal healthy range for long periods of time.



The wall assembly lets moisture gradually move to the outer layer of cladding to be released into the air and balances indoor humidity levels. A barrier divides the wall in two zones of moisture buffering.

Timber construction using solid beams and vapour open wall assemblies

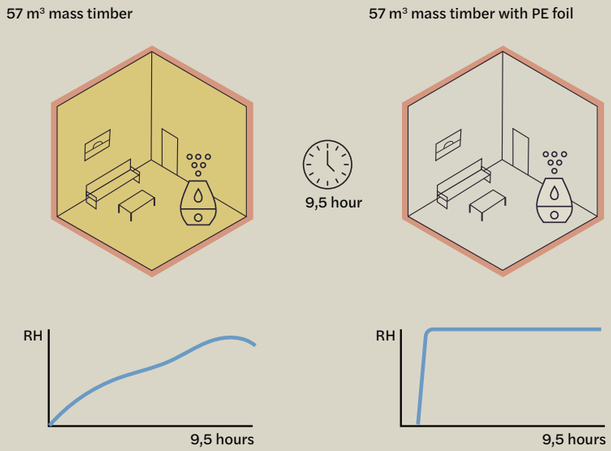
Foil or no foil

A 2017 Norwegian study explored the influence of two types of wall assemblies on humidity levels.[13] They conducted live testing inside two 57 m³ mass timber structures: one featured exposed spruce indoor finishing and the other was lined with a polyethylene foil.

Over a period of 9.5 hours, moisture was introduced into both modules via a humidifier. In the space containing the plastic foil, the relative humidity rose rapidly to 100%. The room with exposed spruce showed a much more gradual rise and a delayed peak, demonstrating the buffering effect of wood surfaces.

Additionally, the surface temperature curves measured in the experiment's wood-exposed module followed the moisture absorption patterns. Indoor temperature rose as moisture was absorbed and latent heat was released, indicating a potential for energy savings.

When the buffering properties of timber are combined with a well-controlled HVAC system, it allows for that system to operate at lower capacity. While these savings are relatively small for heating (2–3%), they are significant for cooling (5–30%). Taking into account the globally rising temperatures, this is certainly an outcome worth exploring further.





→ **Recap** Balancing humidity

- Uncontrolled moisture is a serious health risk **in any building**: damp walls and roofs invite rot and mould, degrading indoor air quality regardless of the materials used.
- A **healthy indoor climate** sits between 40–60% relative humidity (RH) — a range where viruses, mould, and dust mites all struggle, while skin and airways stay comfortable.
- Wood is **hygroscopic**, absorbing moisture when the air is humid and releasing it when the air is dry.
- Unlike mechanical ventilation, **timber regulates indoor humidity** passively — with no energy use, no maintenance, and no emissions required to do that job.

Managing the moisture balance in buildings has long been treated as a mechanical problem, to be solved with fans, ducts, and energy. When integrated properly, ideally in fully breathable wall or roof assemblies, timber passively does part of the work in keeping the indoor air quality at healthy levels.

The dual nature of VOCs in timber

Few people dislike the smell of a woodwork shop, sawmill or timber construction site. Freshly worked timber and brand-new wood products have aromas that are considered pleasant. These come from terpenes, a group of organic chemicals naturally present in wood, which emit that characteristic woody smell. Terpenes are also a good example of a Volatile Organic Compound or VOC.

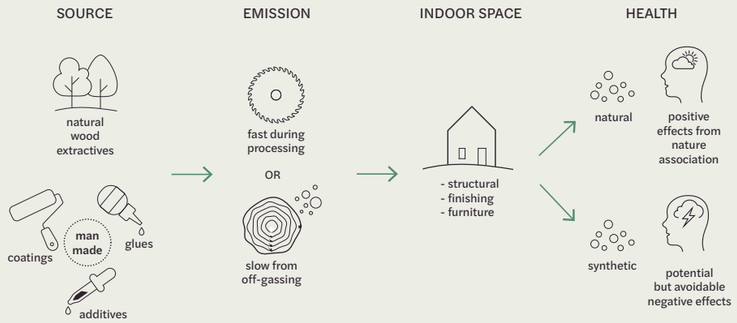
VOC is a characteristic used to designate chemicals that easily turn from a solid or liquid into a gas, even at room temperature. To clarify, the word 'volatile' does not point to any sort of danger or harm. It simply means the compound evapourates quickly. Consider the strong smell of freshly baked bread, the scent of a candle, or a newly painted room. These are caused by VOCs present in the bread, candle wax or paint that are released into the air as gas.

A large collection of chemicals including thousands of different compounds bears the label of VOC. When discussing the presence of VOCs in wood, it is useful to distinguish between the two main sources:

- **Natural or biogenic** compounds: the chemical composition of many plants and trees species includes VOCs.
- **Man-made or synthetic** compounds: chemicals used as glues, additives and coatings in the production of wooden building materials, finishes or furniture.

Because these types of chemicals are easily emitted in gas form and mix with the air we breathe, they can potentially impact our health. However, emission levels of natural VOCs are by far the highest during drying and processing, which happens before a wood product becomes part of a building. After production, what little emission is left gradually diminishes over time.

As studies in the next chaper will show, some natural wood extractives with VOC characteristics are the source of pleasant aroma's that evoke positive associations of nature or have protective properties that bolster the hygienic performance of wooden surfaces.



Structural elements, finishing products and furniture made from timber contain natural and man-made VOCs that end up in the indoor space, generally at low concentrations that don't pose health risks. Some natural VOCs bring health benefits. Some synthetic VOCs can bring health risks, but these can be avoided by careful product selection.



Natural VOCs in wood

Wood is far more than its structural components of cellulose and lignin. Hidden within wood fibres are **extractives**: chemical compounds that constitute 1-5% percent of wood by weight in most softwoods and temperate hardwoods and up to 20% in tropical hardwoods, as these trees produce additional compounds to defend against insects and fungi.

Some of these extractives are characterised as VOCs, namely terpenes, terpenoids, flavonoids, alcohols, aldehydes, and ketones, along with smaller amounts of fatty acids and alkenes.[14] While the term VOC often carries negative connotations in discussions of indoor air quality, the naturally occurring compounds in wood present a more nuanced picture than many building professionals realise.

The specific types and quantities of VOCs vary dramatically by wood species and product. To illustrate the complexity involved in discussing the sources of these compounds, the following **environmental and growth factors** influence VOC content in timber:

- Tree age
- Tree genetics
- Wood cut location in the log (sapwood vs. heartwood)
- Tree growth locality
- Soil quality and nutrition
- Weather and climate conditions
- Air pollution and fertilization

Adding to that complexity is the fact that the emission of these natural compounds is not constant, but varies with processing methods. For instance, thermal treatment significantly accelerates the initial release of terpenes but ultimately reduces their quantity in the final product. Drying operations can also change the VOC profile, with certain compounds only forming after the wood is cut from the tree and begins to dry.

As a result, it should be noted that determining the effect that VOCs in a wood product can have on the health of occupants in a building or space always requires **product-specific analysis**.

Synthetic VOCs in mass timber

When planks, wood fibres, particles, strands, or veneers are transformed into engineered wood products, they are bonded with various chemical compounds and additives. Subsequently, the VOCs contained in substances such as glues, adhesives, varnishes, lacquers, diluents, curing agents, and paints are thereby introduced into buildings and spaces as well.

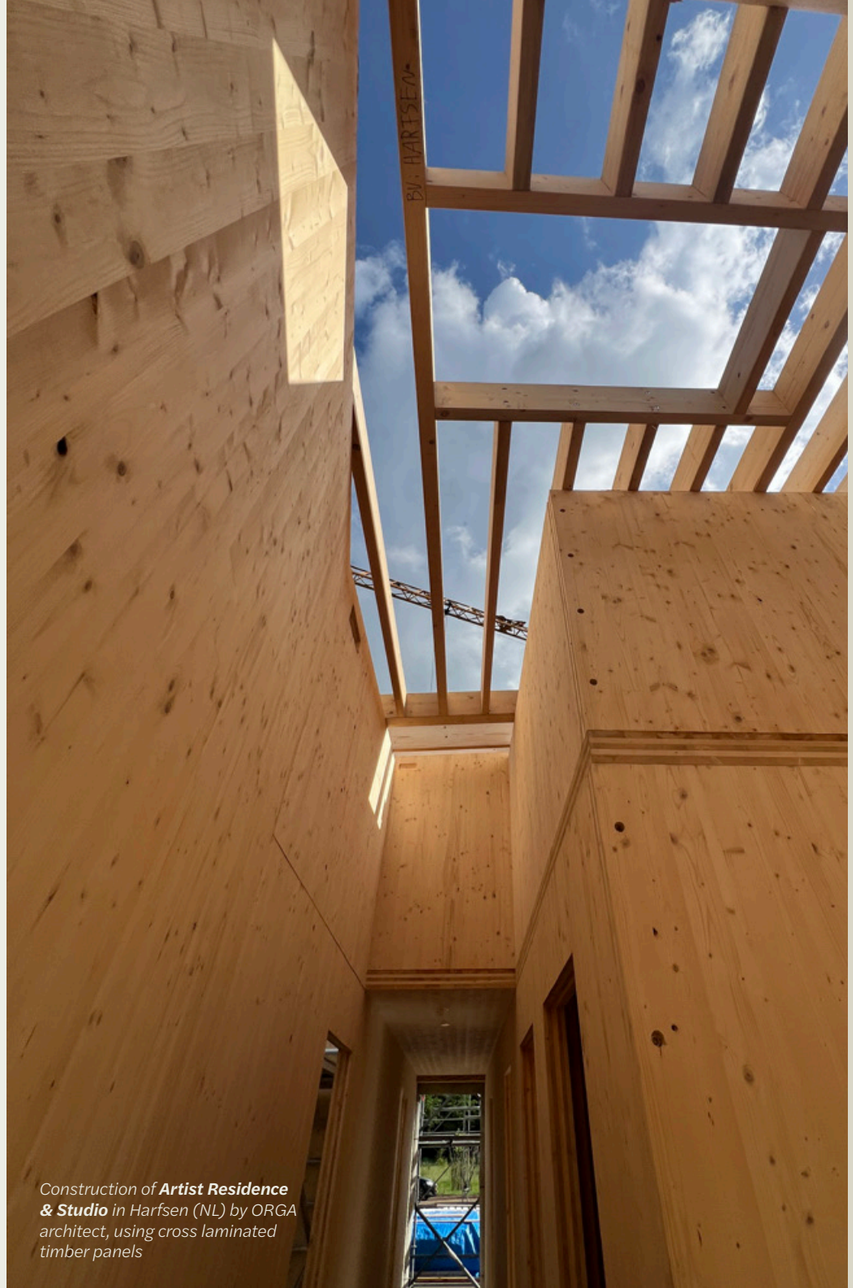
As the Norwegian study on one of the next pages demonstrated, VOCs are not only introduced by wood products, but also by furniture upholstery, curtains, carpets, and cleaning agents. The indoor air pollution caused by these types of VOCs is often mentioned as a cause of the symptoms collectively designated as 'sick building syndrome'.

Timber construction methods using CLT panels are rapidly emerging this last decade and sometimes even designated as a replacement for concrete. The adhesives used in CLT fall into two categories: formaldehyde-based and formaldehyde-free. This is an important distinction, as formaldehyde is toxic at certain concentrations and a known carcinogen. The presence of this chemical in living or working spaces must be avoided.

The use of adhesives and regulatory aspects differ between the European and North American markets. Europe leans heavily toward one-component polyurethane (1C PUR), which is formaldehyde-free. Adhesives that do contain formaldehyde remain in use, but as awareness regarding the harmful effects has grown over the past decade, their use is gradually being phased out.

North America uses both polyurethane (PUR) and melamine-formaldehyde (MF). The regulatory structure currently exempts structural CLT from formaldehyde testing even where formaldehyde-containing MF is used, placing more weight on adhesive selection and voluntary low-emission certification than on a mandatory test.

Relatively new developments are biobased adhesives based on soy-protein and tannin/lignin adhesives. Another alternative is adhesive-free dowel-laminated timber (DLT). These are emerging specifically to eliminate formaldehyde and reduce petrochemical content, meeting the low-emission direction of the market.



*Construction of **Artist Residence & Studio** in Harfsen (NL) by ORGA architect, using cross laminated timber panels*

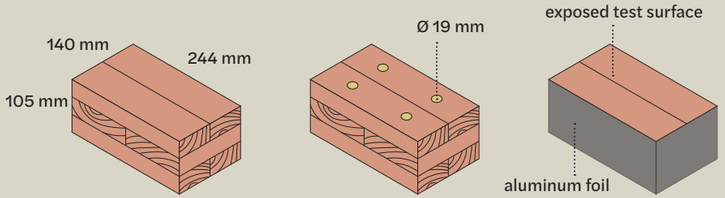
Formaldehyde in CLT

The choice of adhesive in CLT production is a determining factor in whether a building will meet healthy air quality standards. A 2020 study at the University of Oregon measured the formaldehyde gas released from four different Douglas-fir CLT panels from the US market.[15] The experiment centred on comparing the VOC emissions of four types of CLT samples:

- A commercially produced panel bonded with a melamine formaldehyde (MF) adhesive, aged eight months prior to testing.
- A panel bonded with a polyurethane (PUR) adhesive.
- A panel bonded with a new soy-based cold-set adhesive.
- A panel assembled using beech dowels

The sample using the PUR adhesive — by far the most widely used in Europe — yielded formaldehyde levels at or below 2.5 µg/m³. The plant-based adhesive and the non-adhesive dowelled method also showed low levels. The sample with an MF adhesive emitted formaldehyde to the indoor air in a concentration of 54.4 µg/m³, six times the limit of 9.0 µg/m³ then considered acceptable by the California Department of Public Health.

These results demonstrate that MF-bonded CLT, while not a high emission risk, does have the potential to bring formaldehyde into the indoor environment, even months after production and that looking out for safer alternatives is warranted.



Schematic drawings of the CLT samples used in the test setup during the University of Oregon experiment. A) Cross-laminated timber sample dimensions. B) Dowelled CLT sample assembled with four beech dowels. C) Exposed surface area of samples during the test. Adapted from Yauk et al. - 2020.[15]

Determining the source

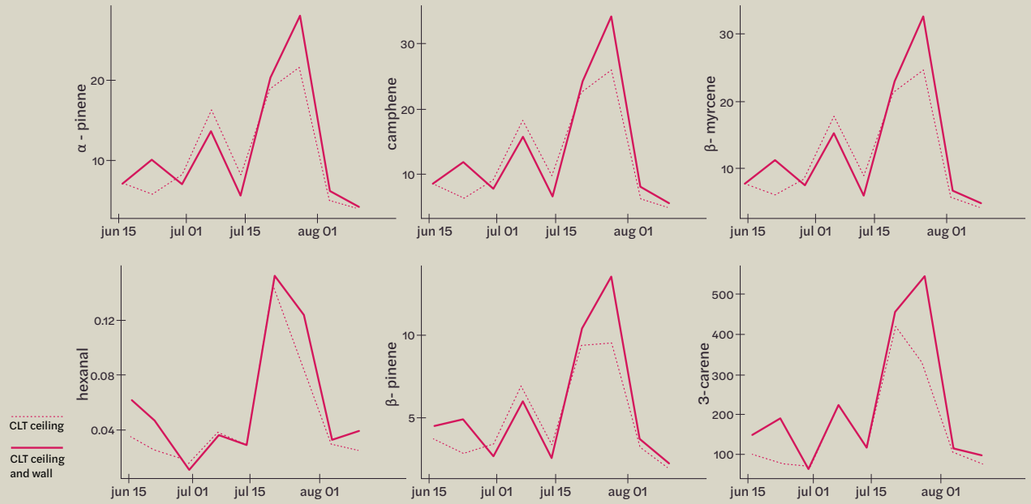
A 2023 Norwegian study investigated VOC emissions during the construction of a cross-laminated timber (CLT) building.[16] During the last 9 weeks of the construction of a student housing complex, air samples were taken from two rooms, one room with an exposed CLT ceiling, and one with both an exposed CLT wall and ceiling. The samples were subsequently tested for the presence of six types of VOCs.

Based on the knowledge that emissions from fresh wood gradually decline over time, it was expected that this would be the case as the wood from the CLT building elements aged over the course of the experiment.

Instead, VOC concentrations peaked during weeks 6 and 7, coinciding with the introduction of curtains and sofas in week 6, and desks and office chairs in week 7.

There are a couple of interesting takeaways here, starting with the finding that all measured VOC concentrations remained below the Lowest Concentration of Interest (LCI) values as recommended by the European Commission.[17]

While CLT is a known emitter of biogenic VOCs, the room with less exposed CLT surface area sometimes showed higher VOC levels, further suggesting that furniture, cleaning agents, and human activity were significant contributors. The emission spikes that correlated with the introduction of curtains and furniture suggest that any effort towards limiting VOCs in buildings should prioritize those potential sources.



VOC emissions measured during nine weeks of construction in a room with an exposed CLT ceiling and a room with both exposed CLT ceiling and walls. Adapted from Bakke et al. - 2023.[16]



*The **HasleTre** office building in Oslo (NO) by Oslotre Arkitekter features a steel-free construction system, consisting of glulam columns and beams joined with beech dowels and CLT walls and slabs utilising X-fix connectors.*

Considerations on VOC-related health effects

Providing a complete and actionable overview of the VOC related health effects would require processing a significant amount of data. Composing a profile for each type of VOC present in wood products, and its effects on occupants across different space types, would be a step in the right direction, one that could lead to more effective regulations.

In any case, such an effort lies well beyond the scope of this report. Instead, the following provides a set of general considerations that can inform decisions when choosing materials.

Formaldehyde-free adhesives

The wood industry has made significant progress in developing healthier materials and many top-quality CLT panels now use modern, zero-formaldehyde adhesives. To be on the safe side, careful screening of CLT products for harmful formaldehyde content is currently still recommended. In some instances, formaldehyde-based adhesives such as melamine formaldehyde (MF) or melamine-urea-formaldehyde (MUF) are still in use.

There are differences between the European and the North American markets on this front. Not that one region is safer than the other, but Europe has moved toward an inherently formaldehyde-free adhesive (1C-PUR), while North America depends more on thoughtful adhesive selection and suppliers that voluntarily provide low-emission certifications.

Source control

A recurring feature in industry reports, regulations, and guidelines is a prevailing reliance on a building's ventilation system to clear out harmful VOCs from the indoor air.

A US study on chronic health risks suggests it should not be the only method for a healthy environment.[18] Findings pointed to PM2.5 size dust particles and formaldehyde VOCs in the indoor air as the biggest health concerns and showed that the cleansing effect of increased ventilation rates proved insufficient. In the case of the VOCs, formaldehyde levels remained above safety levels in 20–50% of the cases, depending on the building type.

Rather than simply boosting ventilation, focusing on enhanced filtration and source control is recommended as the primary approach. This means that a thoughtful selection of building materials, types of finishes, furniture components, and textile products for the interior is key to reducing health risks.

→ **Recap** VOCs in timber

- VOCs in wooden buildings come from two sources: **natural** compounds released by the wood itself, and **synthetic** compounds from the glues, adhesives, and coatings used in processed wood products.
- **Emission of natural VOCs declines** as the material ages. In addition, research links them to measurable stress reducing effects on building occupants.
- The one VOC-related risk worth managing is **formaldehyde**, found in some adhesives used in engineered wood panels — but the industry has largely moved to adhesives that don't contain or emit it.
- VOCs from furniture, curtains, carpets, and cleaning products are typically **bigger contributors** to poor indoor air quality than structural timber itself.

Avoiding wood products over VOC concerns means missing out on a material with genuine health benefits. With the right material choices — particularly formaldehyde-free adhesives — both source control and ventilation do the work of keeping indoor air healthy.

Wooden surfaces and hygiene

Timber has long been excluded from healthcare environments due to a widespread perception that it is not hygienic. Architects, engineers, and consultants often assume that wood surfaces harbour bacteria and are difficult to clean, a perception that leads to a preference for plastic, steel, and other non-porous materials in hospitals and care facilities. This assumption has shaped building codes, policies, and design standards across the healthcare sector.

Emerging scientific evidence challenges this conventional wisdom. Research demonstrates that wood possesses two natural properties that have an antimicrobial effect: its chemical composition and its physical structure. This section examines these hygienic properties and discusses their implications for healthcare facility design and spaces in general.

Naturally clean

Wood contains natural chemical compounds known as **extractives** that protect against degradation caused by microbes. Some, but not all, were discussed in the earlier chapter on VOCs. These protective chemicals include tannins, phenolic acids, flavonoids, terpenoids, and alkaloids, and have distinct antimicrobial properties.[19]

Throughout history, traditional medicine has made successful use of these substances, a fact that is now gradually being confirmed by modern science. The types and quantities of these extractives vary among different types of wood, which explains why antimicrobial effectiveness differs between species.

Wood is also naturally **acidic**, with pH values ranging from approximately 6 for poplar and fir to as low as 3.5 for oak species. This acidic environment makes it more difficult for microbes to survive and multiply once they have landed on a wooden surface. Natural antimicrobial compounds and surface acidity are characteristics of wood that are absent from the neutral surfaces of inert materials such as plastic and steel.[20]

The physical structure of wood contributes significantly to its antimicrobial behaviour, primarily through its hygroscopic properties and its **porous structure**. Most bacteria and many fungi require water to take in nutrients and grow. Assuming that the wood in building materials is properly dried during production and protected during construction, it will not have a moisture content that provides sufficient water for microbial growth and multiplication.

The **hygroscopic** nature of wood allows it to absorb moisture, as discussed in the earlier chapter on moisture buffering. In the event of contaminated droplets landing on a wooden surface, the fluid is absorbed into the material, effectively leaving any bacteria present on the surface to dry out and perish.

Hygroscopic and porous

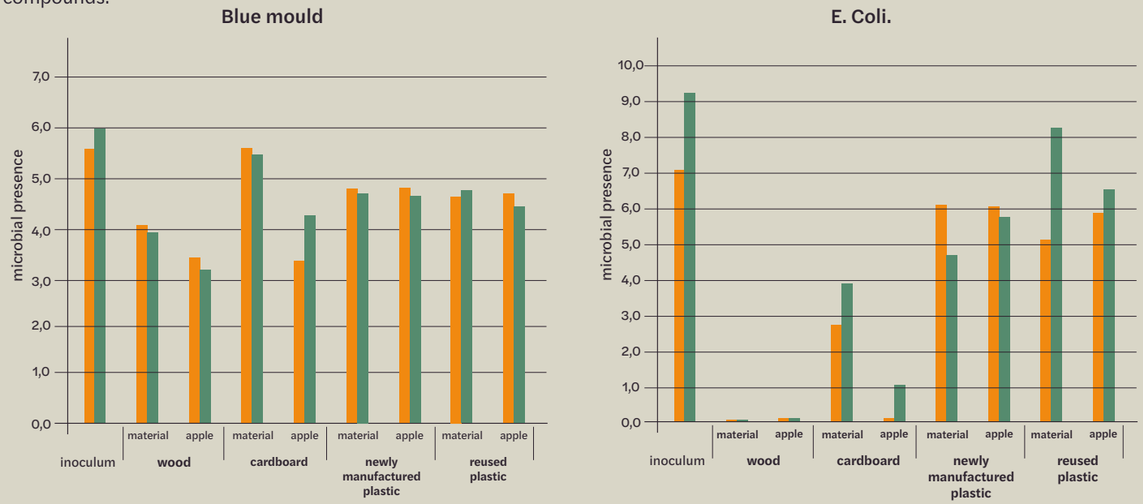
These properties explain why microbes survive for shorter periods on wood than on the smooth, non-absorbent surfaces of plastics and metals. A study of kitchen cutting boards observed that the seafood-related Vibrio bacteria survived for shorter periods on absorbent materials like bamboo and wood compared to smooth surfaces such as plastic, stainless steel, and glazed ceramic.[21] This difference was attributed to the prolonged retention of moisture on smooth surfaces, which sustains bacterial survival.

Some concerns have been raised that bacteria might shelter within wood pores and evade removal during cleaning. While some microbes may penetrate the porous structure of wood, survival would still require a moist, non-acidic environment free of antibacterial compounds.

A French study compared the survival rate and transferability of pathogens on four different packaging materials: poplar wood, cardboard, new plastic and reused plastic.[22] Each material was inoculated with both Blue Mould and the E. Coli bacteria and then brought in contact with apples to test transferability.

The poplar wood demonstrated superior hygienic properties, presenting the lowest survival and transfer rates among all tested materials. In contrast, both the plastic surfaces showed the highest transfer rates.

The researchers attributed the strong performance of the wood surface to a combination of three factors. The hygroscopic nature of the wood caused bacterial cells to dry out and natural antibacterial compounds in the wood further inhibited bacterial survival. In addition, the porous structure of the wood surface entrapped the microbes, preventing them from transferring to other surfaces, in this case apples, though the same principle applies to human hands or clothing.



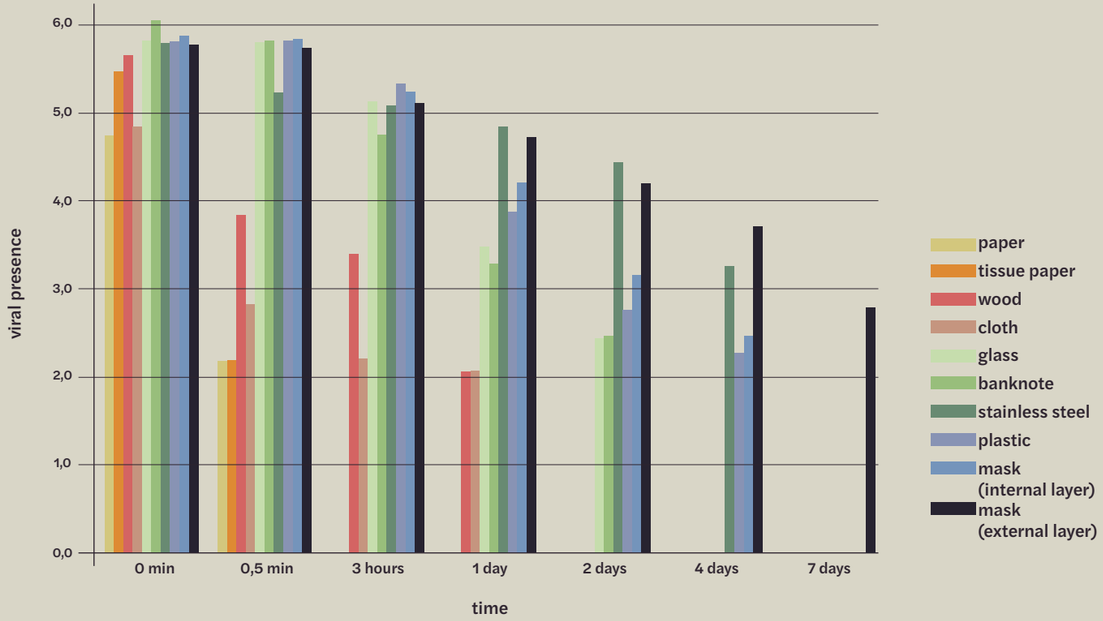
The presence of the two types of microbes on the material and the apples after 1 week. The test was performed twice: the orange bars show the first test, green the second. Adapted from Aviat et al. - 2020.[22]

Wood vs viruses

The studies above are just some examples out of many where wooden surfaces outperform materials conventionally used in healthcare settings when it comes to pathogens. One of the more striking cases concerns the SARS-CoV-2 virus, responsible for the COVID-19 pandemic.

A study at the University of Hong Kong examined viral survival across a wide range of materials, including printing paper, tissue paper, wood, cloth, glass, banknotes, stainless steel, plastic, and surgical masks.[23] After two days, the infectious virus was no longer detected on wood or paper.

It took more than two days to reach the same result on glass and banknotes. On stainless steel and plastic it took four days, and after seven days the virus was still detected on the outer layer of surgical masks.



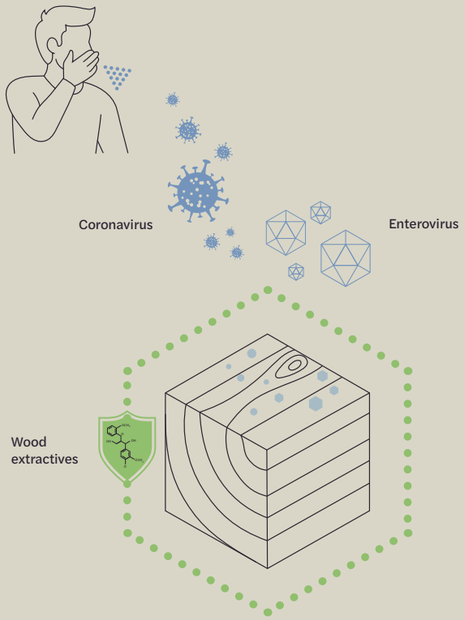
Graph created by Florence Aviat at YouR Research, based on Chin et al. - 2020.[23]

Anti-viral compounds

In a collaborative effort by universities in Finland and Sweden in 2024, a research team further investigated the antiviral properties of wood by comparing six different species: pine, birch, alder, eucalyptus, oak, and spruce, against both corona- and enteroviruses.[24] They concluded that the antiviral activity of wood is potent, rapid, and primarily governed by its chemical composition. Four key classes of natural compounds or extractives in wood contribute to the antiviral properties: resin acids, lignin, phenolics, and terpenoids.

It is worth repeating that the chemical composition of wood species varies considerably. Therefore, the antiviral effectiveness depends on the type of wood and the specific virus being targeted. For example, the high concentrations of resin acids and terpenes in pine and spruce proved a strong counter against coronaviruses, while the high phenolic content in oak explains its effectiveness against enteroviruses.

An important sidenote mentioned in the study: processes such as combining wood with plastic, applying thermal treatments, or using surface coatings can compromise the naturally present antiviral properties. But the main takeaway is that untreated wood surfaces can serve as a natural and effective barrier against the transmission of viruses. This presents promising opportunities for use in the creation of public spaces and other high-contact spaces, to enhance infection control.



Healthcare environments

The scientific evidence on wood's hygienic properties has implications for how care facilities could incorporate this material to optimise their healing environment. An exclusive focus on chemical agents and high-tech systems has rendered many twentieth-century hospitals entirely devoid of natural elements. Integrating wood into the interior is an effective means of introducing naturalness to spaces and to the patient experience, which can unlock all sorts of mental health benefits, as will be discussed in a later chapter.

In practice, the challenge here is to match the aesthetic and psychological benefits of wood with the hygiene requirements for high-contact surfaces. A balanced approach will bring the optimal result, specifically designed for the type of healthcare space at hand. While untreated wood might not be suited for spaces such as cleanrooms or operating theatres, it can be used extensively throughout a healthcare facility through the application of proper zoning principles to the building design.[25] Clearly defining room categories allows for the appropriate application of wood where hygiene risks are lower and the potential boost from increasing comfort and naturalness is high.



Hallways, waiting rooms, offices, cafeterias and meeting rooms obviously require proper hygiene, but patients, staff and visitors would also benefit greatly from a warm, friendly atmosphere. Surfaces should be clean, but do not need to be resistant to harsh cleaning agents. As the evidence above demonstrates, high-contact surfaces such as handles and railings made from untreated wood are entirely viable in these spaces. Patient rooms and laboratories have higher requirements but the mental health benefits of wooden materials can also improve recovery and work performance.

If needed to fulfil the requirements of specific zones, coatings can help to protect wood surfaces against aggressive cleaning agents and degradation through wear and tear. These range from less chemically resistant oils and waxes derived from natural ingredients to synthetic PUR and epoxy coatings with high resistance to cleaning agents.

When applying coatings, there is a clear trade-off between protecting the wood and maintaining the beneficial natural properties as coatings can compromise the wood's moisture-buffering capacity and inhibit the antibacterial extractives from counteracting pathogens. But as long as the coating is transparent, the visual benefits of wood can still have a positive effect, even in high-risk spaces.



*Dental practice **Mondzorg Middenmeer** (NL) by ORGA architect*

→ **Recap** Wood and hygiene

- Wood has long been kept out of healthcare settings on the assumption it harbours bacteria, but the evidence points the other way: wood can **outperform conventional materials** on hygiene.
- Wood is **naturally antimicrobial**. Its chemical extractives and acidic surface make it a hostile environment for bacteria and viruses to survive.
- Its **porous, hygroscopic structure** adds a second defence: it absorbs moisture from contaminated droplets, drying out and immobilising bacteria before they can transfer to other surfaces.
- Wood isn't a hygiene compromise in healthcare design. In many areas, it's the **better-performing choice**.

In healthcare environments, wood offers a rare combination: a surface that resists pathogens and a presence that calms the people around it. Smart zoning makes this easy to apply: untreated wood in lower-risk spaces like corridors and waiting rooms, transparently coated wood where stricter hygiene rules apply.

2 Mental health

While almost everyone can see the importance of exercise and eating well to take care of the body, the realisation that mental health deserves equal attention has only recently begun to take hold. As society's attention to mental health has been gaining traction, the volume of research dedicated to wellbeing has grown considerably. Scientific fields such as environmental psychology, neuro-architecture, and biophilic design have led to a surge in studies that explore how the built environment interacts with the mind.

The following chapter on mental health discusses the combined physiological and psychological impact of wood. By providing insight into why the properties of wood are processed by the human datacentre the way they are, we can learn how to maximise their benefit in the buildings of the future.

*Plenty of daylight and a view of the natural landscape when visiting dental practice **Mondzorg Middenmeer** (NL). The design by ORGA architect uses the calming effect of nature to reduce stress among patients through a specific selection of biophilic principles. One of which is the accentuated wood texture of the walls and columns.*

Nervous system

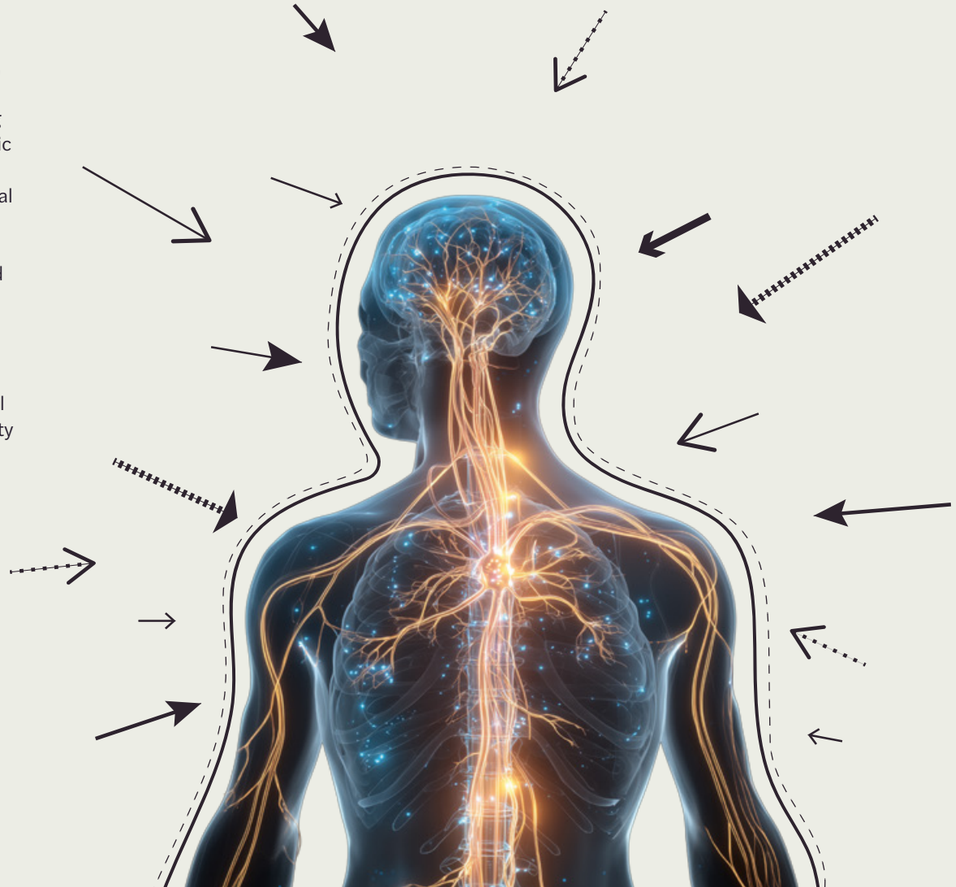
Humans exist in a continuous state of interaction with their environment. Whether awake or asleep, the human body is constantly processing large amounts of information. A person's health and wellbeing is dependent on the body's capacity to detect and adapt to changes in information or stimuli. To further understand the properties of wood that can influence health, we next explore how people experience their surroundings.

The amount of data being processed that we are actively aware of is extremely limited: out of the 11,000,000 bits of information per second that the body collects and sends to the brain, only 50 bits are processed by the conscious brain.[26] This takes place through a complex system of physiological adjustments and experiences, which are deeply interconnected in their operation.

Each component could be broadly described as follows: the physiological refers to measurable, physical shifts in bodily function, while the psychological encompasses qualitative experiences of the mind through emotion and cognitive interpretation.

As the following sections demonstrate, a considerable body of research points to wooden surfaces positively affecting wellbeing through both the sympathetic and the parasympathetic nervous system. This psychological-physiological adaptive mechanism operates as a constant back-and-forth interaction between the nervous system, brain and body.

Although research clearly indicates there being a physical component to our response to wood, the term 'mental health' has been adopted here for clarity and readability. The following chapter examines this category of health benefits in greater depth, starting with exploring the question of why wood evokes a positive impact on our minds.





The Autonomous Nervous System

At the heart of our adaptiveness lies the autonomous nervous system (ANS), which functions as a bridge between environmental stimuli and the body's internal state. This system, operating largely beyond our level of awareness to maintain balance, is composed of three separate subsystems:

- The **Sympathetic Nervous System** (SNS), often referred to as the 'fight or flight' system, functions to mobilize our body's resources for action in response to danger, stress or physical exertion.
- The **Parasympathetic Nervous System** (PNS), also known as the 'rest and digest' system, conserves and helps regenerate energy during periods of calm and returns the body to a state of equilibrium after activity.
- The **Enteric Nervous System** (ENS), a vast and complex system that regulates the digestive tract. This will not be further discussed here, as there is no indication of any relation between the ENS and the presence of wood.

Perception

When people enter a room with wooden features, their response is rarely neutral. Something about the material seems to engage the senses in a way that few other materials do. Its warmth, texture, grain patterns, and even its subtle scent all contribute to a layered experience that goes far beyond aesthetics alone. Understanding how and why people respond to wood in spaces is therefore not just a matter of design preference. It is a question with meaningful implications for how indoor environments are planned, built, and inhabited.

Human perception of wood in interior spaces is influenced by a range of factors, including the species and surface treatment of the material, relative proportion of visible wood in a room, and the context in which it is used. Examining these factors is essential for professionals seeking to make informed, evidence-based decisions about the use of wood in the spaces they design and build.

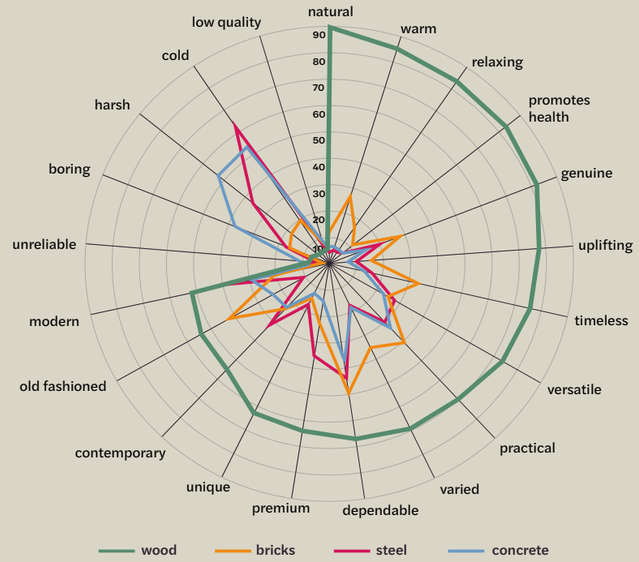
Through surveys, self-reporting tools and even brain scans, many studies have explored how the presence of this natural material is processed by the senses and the brain.

*Living room at **House in a Hill** in Utrechtse Heuvelrug (NL) by ORGA architect*

Wood in the workspace

A 2018 Australian study surveyed 1,000 indoor workers to investigate the relationship between wood exposure in workplaces and worker wellbeing.[27] The research built on the biophilia hypothesis: the idea that humans have an innate need to connect with nature. When asked how they experienced any wooden materials in their workspace, many of them had positive associations, especially when compared to equivalent experiences with materials such as bricks, concrete, and steel:

- Wood received near-maximum scores for qualifications such as ‘natural’, ‘warm’ and ‘relaxing’, results that were broadly anticipated.
- Wood scored significantly higher on more abstract values such as ‘health promoting’, ‘genuine’, and ‘timeless’.
- Wood scored twice as high in categories where conventional materials might be expected to be competitive. For instance ‘practical’, ‘dependable’, ‘premium’, or ‘contemporary’.
- Both concrete and steel outscored wood with negative qualifications by a large margin, such as ‘boring’, ‘harsh’, and ‘cold’.



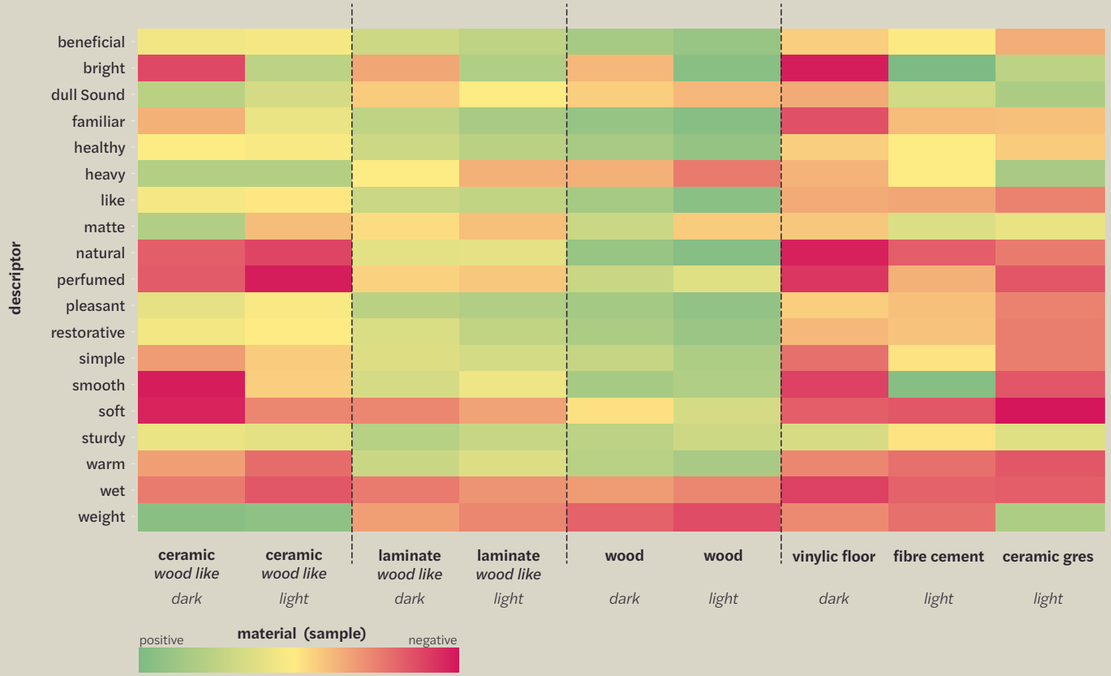
Subjective qualifications of how the participants perceived material features in their workplace. Adapted from the survey by Pollinate - 2018.[27]

Multisensory experience

The perception of natural materials in comparison with synthetic materials has also been examined under controlled conditions. A 2022 study at the University of Padova involved 24 participants in a multisensory evaluation of nine common building materials.[28] Samples of nine wooden, wood-like, and synthetic building materials were presented to participants who were asked to explore each sample through vision, touch, and smell.

Each sample was rated using a questionnaire with eighteen bipolar scales, for example ‘natural’ vs ‘artificial’ or ‘pleasant’ vs ‘unpleasant’. Using these subjective criteria allowed participants to express the full range of their personal perceptions of the materials. With the exception of a few outliers, the real wood samples received the most positive qualifications, with the wood-like laminate a close second.

These and many other studies show that people perceive wood as a warm, natural, and living material that positively influences the quality of their surroundings.



Heatmap of questionnaire outcomes from the Padova study. Adapted from Dematté et al. - 2022.[28]

Personal sentiment

An international research group conducted the Wood2New survey study across five European countries in 2018 to gather perceptions and views using more open-ended questions.[29] This allowed the 60 participants to respond without the question itself setting boundaries or providing clues for responses, leaving room for more detailed and personal responses.

This approach led to additional insights supporting the idea that the naturalness of wood relates to the nature of humans. For example, people expressed the importance of being able to tell the origin of the material, appreciating wood’s honest and recognisable qualities. One participant noted that there is ‘an unconscious comfort in seeing what things are made of’.

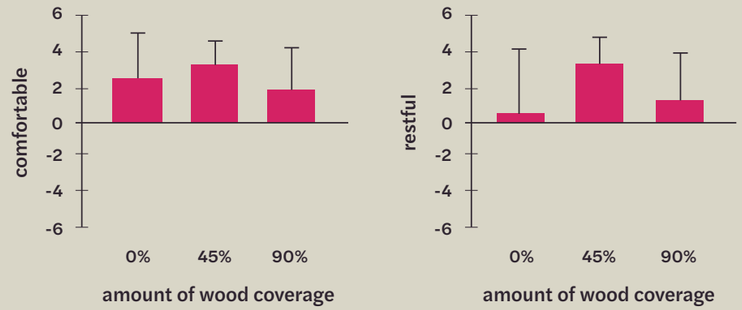
Participants also indicated that visible wear and aging of wood contributes to them developing an affection or attachment to a space over time. These kinds of sentiments cannot easily be quantified, but nonetheless indicate a deep and positive connection between wood and mental wellbeing.

Surface coverage

Some research on the perception of wood suggests that there is an optimal amount of wooden surface area in a space that people find comfortable. An early Japanese study introduced 15 participants to three life-size rooms with different amounts of wood coverage: 0%, 45%, and 90%.[30] Participants were then asked to rate their experience.

The room with a 45% wood ratio was rated as the most comfortable, restful, and also resulted in lower blood pressure. In contrast, the 90% wood ratio room initially produced lower blood pressure, suggesting a positive response.

However, this was followed by a rapid decrease in brain activity and a spike in pulse rate. This indicated to the research team that the positive effect of the near-full wood coverage was not sustained and may have become tiring or overwhelming to experience for the subjects after the initial boost. The 0% wood room, which subjects perceived as artificial, produced the smallest change in autonomic nervous system activity.



Diagrams displaying the scores on comfort and restfulness for three rooms with different wood coverage. Adapted from Tsunetsugu et al. - 2006.[30]



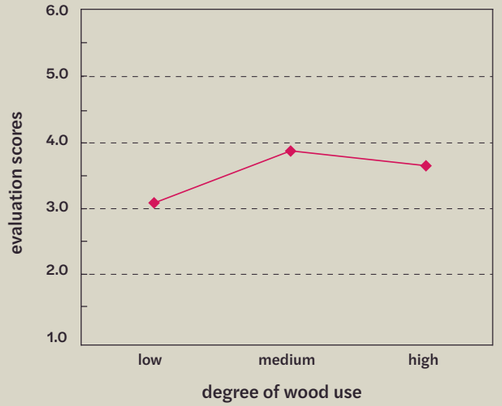
Variety matters

A 2021 study of wood coverage built and expanded upon earlier findings.[31] This time, the research team examined how 75 participants experienced the percentage of surfaces covered in wood, the variety in wood species and their application across different surfaces, like floors, walls, and beams.

Using eye-tracking technology and spatial images of rooms with different coverage and variety, they found that 50–65% wood coverage was optimal for experiencing comfort, relaxation, and desire to use the space. Low coverage of under 20% was determined insufficient for creating warmth and naturalness. High coverage of 80% made spaces feel narrow and too enclosed for some of the participants.

Analysis also showed that the wood surface variety had a greater impact on visual attention than wood coverage alone. The research team concluded that greater variety in wood surfaces can reduce the feeling of enclosure that a large, monolithic surface might create, which explains why a higher percentage of wood coverage – up to 65% – was perceived positively compared to the 45% threshold reported in previous findings.

The open-ended Wood2New survey mentioned earlier supports these findings.[32] Many participants preferred indoor environments that combined different wood types with a variety of other materials. For some of the respondents, using wood on all or many surfaces created an oppressive sense of enclosure or claustrophobia.



Graphic representation of the evaluation scores, displaying the highest values at medium degree of wood use. The mean scores indicate the psychological impression that the images left on participants. Adapted from Li et al. - 2021.[31]

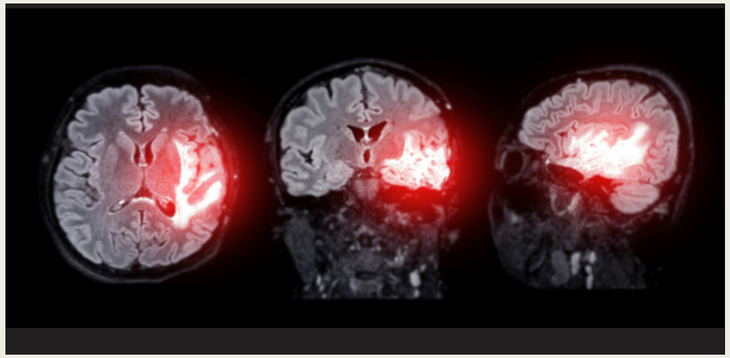
Whole brain analysis

In a 2025 study, Belgian and Dutch researchers used the latest technology to explore the associations the human brain makes with wooden surfaces.[33] They approached this topic by distinguishing between two modes of thinking.

On the one hand, human perception uses fast, automatic, emotional, and intuitive processing to quickly make sense of things. On the other hand, slow, deliberate reasoning and conscious thought allow for deeper understanding.

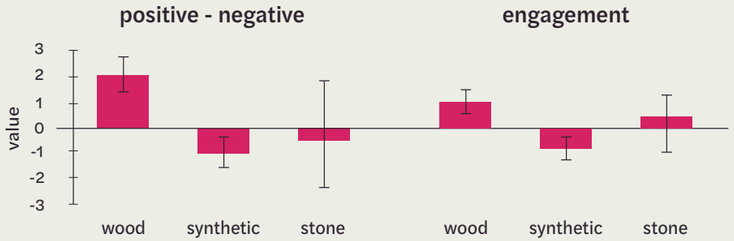
By using neuro-imaging techniques, the researchers zoomed in on the implicit emotional responses of the first mode, given that participants in previous studies may not have consciously recognised or reported these implicit emotional responses.

They conducted the 'whole brain analysis' using functional magnetic resonance imaging (fMRI) to scan the brain activity of 24 participants during cognitive tasks, one of which involved viewing images of living rooms, classrooms, hospital rooms, and office spaces, each presented in three material variations: wood, stone, and synthetic materials.

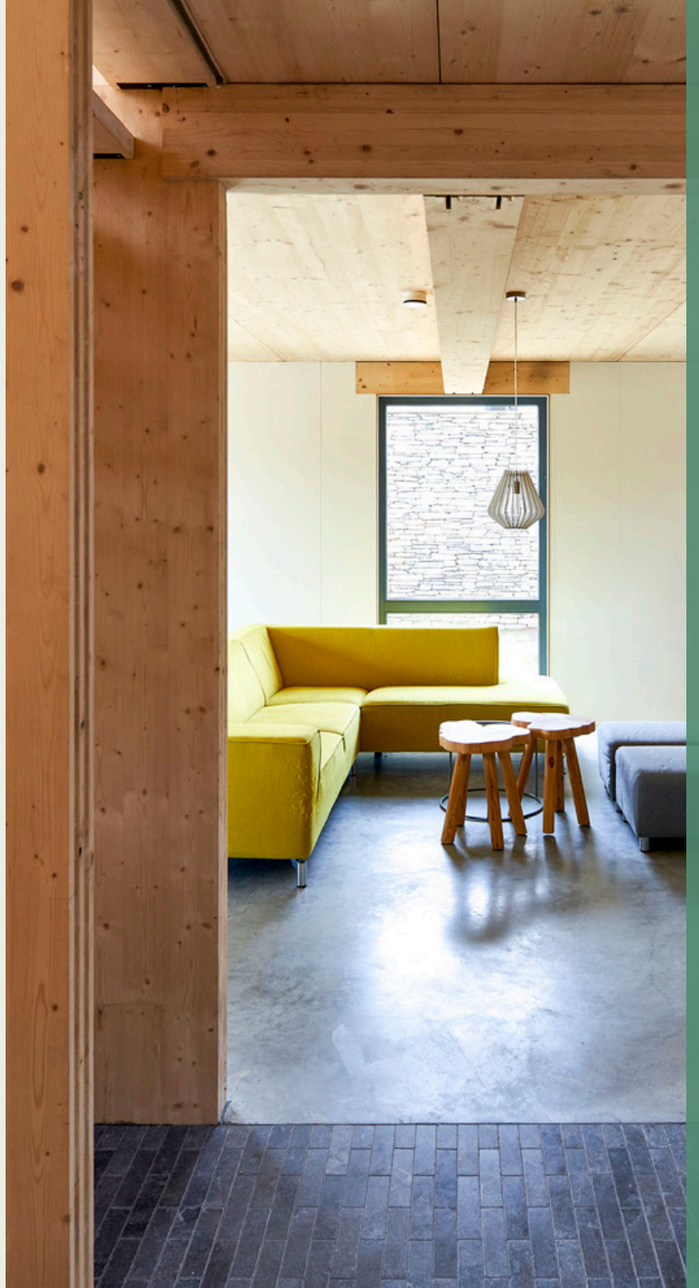


Images with wood consistently produced increased engagement and positive emotions, and caused fewer feelings of annoyance and anger than the other materials. But the results of the brain imaging combined with a set of questionnaires did more than just confirm the positive perception of wood in spaces.

The researchers created a framework that categorises the brain responses into positive emotions, negative emotions, level of impact, and amount of engagement. Through this framework, the emotional mechanisms in the brain that cause the positive response were revealed.



Comparison of the positive or negative brain responses that the materials in the images evoked and the level of engagement. Adapted from Laureys and Scholte - 2025.[33]



→ **Recap** Perception of wood

- People's response to wood goes **beyond aesthetic preference** — its warmth, grain, texture, and scent engage the senses in ways most building materials simply don't.
- Open-ended surveys reveal something deeper: people value being able to see what a material is made of, and the **visible wear and aging** of wood builds a sense of familiarity over time.
- There seems to be an **optimal range** for wood coverage, roughly 45–65% of visible surfaces — too little reads as insufficient, too much can feel oppressive.
- **Variety outperforms quantity**: mixing wood types, colours, and placement across floors, walls, and ceilings beats a single uniform surface, even at high coverage.

No other mainstream building material appeals to the senses quite like wood does. Wood just hits differently, in a way that points to something deeper than personal taste.

Stress reduction and relaxation

Chronic stress occurs when the body's stress response systems are activated for long periods of time. It is for good reason that science has been exploring for several decades the potential of wood in the interior space to relieve stress.

Without relief, stress can affect nearly every system in the human body. Cardiovascular disease, weakened immune function, headaches, and joint pain resulting from prolonged muscular tension are just a few examples. In short, unrelieved stress causes significant wear and tear on the body.

Roger Ulrich, in his work on stress reduction theory (SRT), proposed that exposure to nature triggers an automatic, unconscious stress-reducing response.[34] Because humans evolved in natural settings, we are predisposed to find certain natural features calming and restorative. Views of vegetation, moving water, or the natural colours and patterns of wood, for instance, can lower heart rate, reduce blood pressure, and decrease stress hormones within minutes.

Over the years, research teams have developed a variety of controlled experiments — simulating real-life situations in which people live or work — in order to study the effects that the presence of wooden surfaces has on stress levels. These studies use several indicators to monitor stress and relaxation, among which responses of the autonomic nervous system, the workload on the heart and cortisol levels in hair or saliva.

Room comparison

Researchers at the University of British Columbia wanted to objectively measure how the body responds to working in office environments featuring wood, plants, or both. In this pioneering 2010 study, the team constructed four identical office rooms, each with a different number of wood surfaces and plants.[35] While spending time in each room performing a challenging maths task and relaxing after, the skin conductivity of each of the 119 participants was monitored using a basic, non-invasive device. This way the researchers tracked modulations in the fight-or-flight response of their sympathetic nervous system.

While the presence of a small number of plants did not appear to have any influence, participants in the two rooms featuring wooden furniture and blinds showed significantly lower overall stress levels, suggesting that the visual presence of wood had an immediate and passive calming effect, even before the task began. Participants also exhibited significantly fewer spontaneous stress responses, indicating a more stable and less reactive physiological state. This way, the study demonstrated a relation between the presence of wood in a workspace and reduced physiological stress.



Baseline



Plants



Wood



Wood and plants

Four identical office rooms for monitoring stress levels during a cognitive test while varying the presence of plants and wooden surfaces.

Wooden flooring

A 2014 study at two universities in Taiwan used EEGs to measure brain activity in 30 participants when viewing wooden and ceramic floors.[36] The volunteers exhibited significantly lower alpha wave activity in the occipital lobe when in rooms with wooden floors.

The occipital lobe is the brain's primary visual processing centre and alpha wave activity is associated with calm, relaxed and aware mental states. The relaxed state shown in the participant's brain activity was confirmed by their self-reports of feeling more at ease and comfortable in the wooden environments.

In addition to the calming effect on the autonomic nervous system seen above, these outcomes suggest that the visual perception of wood was processed by the brain in a way that induced relaxation.

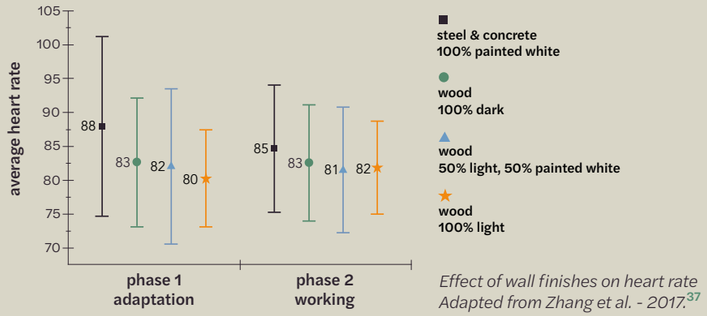
Stress indicators

The network of arteries and blood vessels, with the heart at its centre, works in tandem with the nervous system to prepare and restore the body when confronted with stressful situations. Therefore, blood pressure and **heart rate** are commonly used as metrics to track stress and relaxation levels.

Cortisol is a hormone that the body releases when it feels under pressure. When the brain senses stress, it sends a signal to the adrenal glands to pump cortisol into the bloodstream and get the body ready for action. This is perfectly healthy and useful in small doses, but chronically high cortisol levels can disrupt sleep, affect mood, and impact heart health. Researchers can measure cortisol in blood, saliva, or in a strand of hair as an indicator of the effect that stress has on the body.

Heart rate study

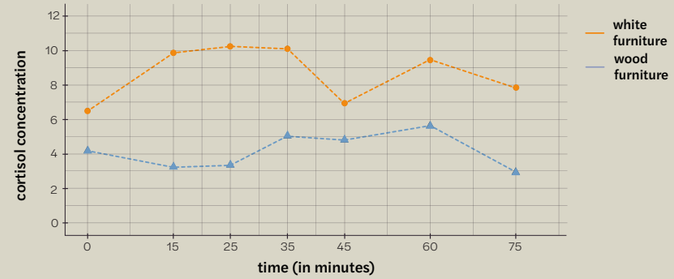
A 2017 experiment at a university in Shanghai asked 20 participants to undergo cycles of work tasks and moments of recovery in a concrete room painted white and three rooms with wood features.[37] Results showed that the heart rates of the participants in the rooms with wood were consistently lower, indicating that their hearts didn't have to work as hard compared to their counterparts in the concrete room.



Effect of wall finishes on heart rate
Adapted from Zhang et al. - 2017.[37]

Cortisol study

A 2020 study in Slovenia used cortisol as a primary biological indicator of stress in 61 participants by comparing responses to a violent movie scene in rooms with oak and walnut furniture against control environments with white furniture.[38] Saliva measurements showed that oak wood furniture significantly reduced overall cortisol levels compared to a control environment. Walnut had less of an effect, which indicated that efficacy may depend on characteristics such as colour and luminance.



Cortisol response pattern for one subject, representing a typical pattern. It takes 25–45 min after the stress event before cortisol reaches the saliva. Levels in the wood room are lower overall and the stress response — visible in the 25–45 min segment — is less intense. Adapted from Burnard and Kutnar - 2020.[38]

Sleep

Sleeping is essential for relaxation, stress relief and overall health. A good night's rest allows both the brain and the body to recover, repair, and regain balance. Among other recovery functions, sleep facilitates a shift in the autonomic nervous system.

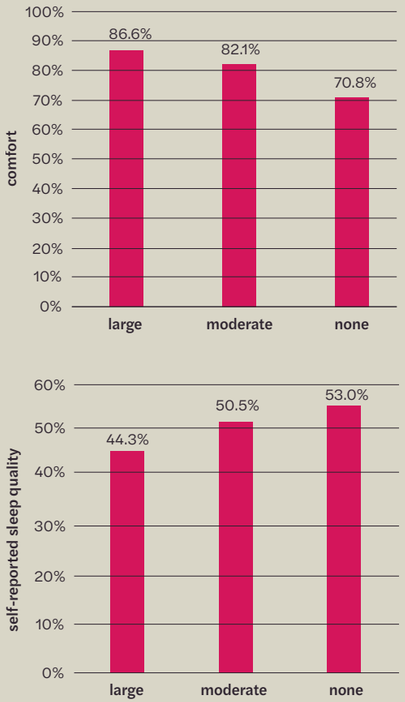
During the day, particularly under conditions of stress, the fight-or-flight system (SNS) is more active. During deep sleep, the rest-and-digest system (PNS) becomes dominant, slowing the heart rate, lowering blood pressure, and directing the body towards repair and energy conservation.

Without adequate sleep, the SNS remains overactive, preventing full relaxation and recovery.

Sleep quality survey

A 2020 study on 671 Japanese workers investigated the association between the use of wood in bedroom design and occupants' comfort and sleep quality.[39] The participants self-reported their sleep quality and insomnia symptoms via surveys. Sleep measurements were taken using an actigraph, a small wearable device that detects movement.

The study found that statistically, a greater proportion of interior features made from wood was linked to greater comfort, fewer signs of insomnia, and better self-rated sleep quality. While a cross-sectional study of this type can only establish associations and does not prove causality, the large sample size and the fact that data were collected in real-life settings lends strength to these conclusions. Keeping in mind that sleep is such a vital part of stress management, these results call for follow-up research that directly investigates the relationship between wood exposure and sleep quality.



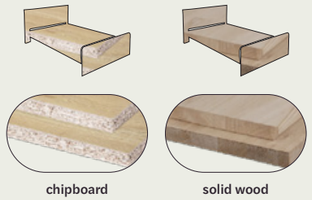
Level of comfort (above) and self reported sleep quality (below) set against the amount of wood features used in the bedroom. Adapted from Morita et al. - 2020.[39]

Wooden beds

A study that focused explicitly on wooden beds took place in Austria in 2021.[40] The researchers explored the connection between the materials that beds are made of and the shift in the nervous system during sleep. A group of 15 participants alternated between sleeping in a bed made of solid, stone pine wood, a wood-like melamine-faced chipboard bed and their own bed (for which materiality varied), which served as a baseline.

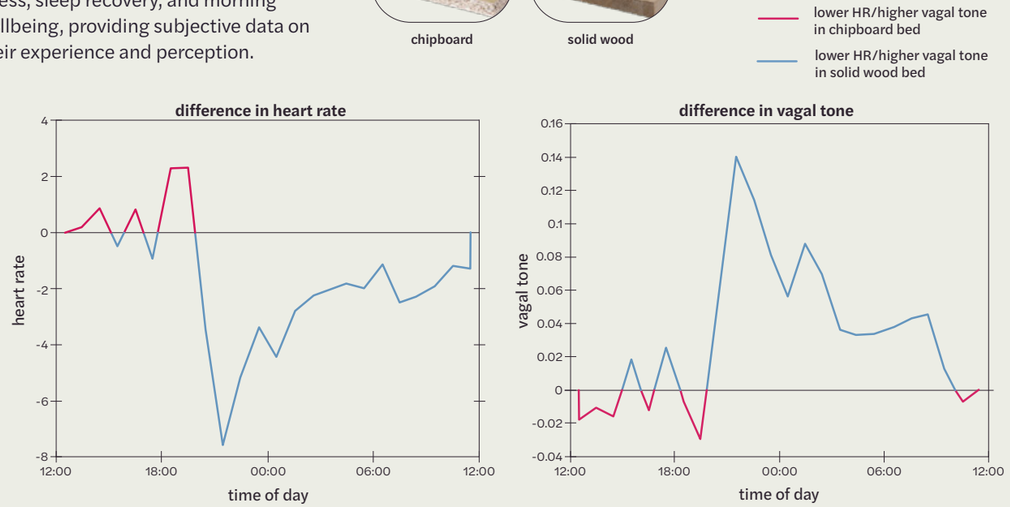
Using an ECG device, several biometrics were measured during 24-hour periods, including heart rate, parasympathetic activity, and the combined rhythm of pulse and respiration. The participants also completed questionnaires to assess stress, sleep recovery, and morning wellbeing, providing subjective data on their experience and perception.

The participants exhibited a significantly lower heart rate and higher parasympathetic activity when sleeping in the stone pine bed, indicating a deeper state of relaxation. Pulse-respiration rhythm was also significantly lower in the stone pine beds and close to the ideal resting ratio. The sleep phase of 'rest-and-digest' recovery lasted two hours longer in the solid wood bed compared to the simulated wood bed, suggesting a prolonged and more stable period of deep relaxation.



The researchers concluded that the use of stone pine wood in a sleeping environment improves the restorative effects of sleep by enhancing autonomic recovery.

Interestingly, participants appeared to distinguish between real and simulated wood even while asleep. Although exact VOC measurements were not taken, the observed effects were consistent with other research that the aromatic compounds of stone pine stimulate parasympathetic activity, suggesting a relationship between wood scent and sleep quality.



Differences in heart rate and vagal tone, which indicates parasympathetic activity. The blue line indicates a lower heart rate and a higher vagal tone at night and well into the morning for the participants in the solid wood beds. Adapted from Grote et al. - 2021.[40]



→ **Recap** Stress reduction

- Chronic stress is one of the leading contributors to poor health — affecting the cardiovascular system, immune function, and mental wellbeing. **Stress reduction theory** proposes that exposure to natural features, including wood, triggers an automatic, unconscious calming response — and decades of research have been testing that claim.
- Spaces with wood surfaces are consistently **linked to lower stress markers**: reduced blood pressure, less heart strain, and fewer spontaneous stress responses.
- These effects show up both during demanding tasks and rest breaks — wood doesn't just help people **relax faster**, it helps them **stay calmer** while working.
- **Sleep quality** is part of the picture too: bedrooms with more wood, or beds made of untreated wood, are linked to better sleep, fewer signs of insomnia, and greater comfort.

Wood's calming effect runs through multiple channels at once. Sight, scent, and touch all converge to lower the body's 'fight or flight' response or increase recovery by activating the 'rest and digest' system.

Cognitive performance

In most offices or classrooms, the day is structured around the assumption that people can move from one task to the next without their concentration ever running dry. In practice, anyone who has sat at a desk through a long afternoon knows otherwise: the capacity to focus is a finite resource that needs chances for recovery.

Long before science gave this phenomenon a name, people instinctively sought out nature to recharge, by visiting a quiet garden, walking in a park, or taking in a view of trees to clear their heads. This idea that natural surroundings can support cognitive performance was advanced by Rachel and Stephen Kaplan.[41] Their attention restoration theory (ART) proposes that natural environments help restore the capacity to focus.

The theory distinguishes between two types of attention:

- **Directed attention**: effortful focus that becomes depleted over time.
- **Involuntary attention**: effortless engagement that doesn't deplete cognitive capacities.

Nature engages our involuntary attention through 'soft fascination': such as watching leaves rustle in the wind, water flowing, or enjoying a natural vista. This gives directed attention a chance to recover, improving cognitive performance and reducing mental fatigue.

Following the development of attention restoration theory and its proposed benefits in educational and workplace settings, several experiments have explored the effect that the presence of wood might have on cognitive performance.



***Forest Sciences Centre** at the University of British Columbia.*

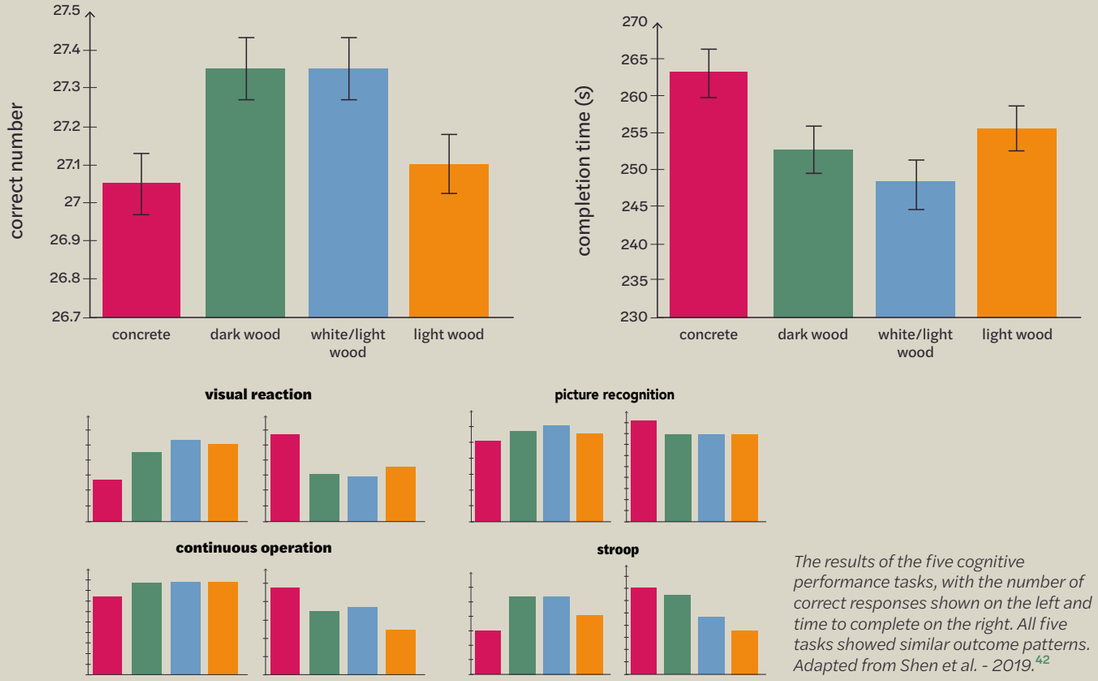
Improved test results

A Chinese study in 2019 investigated how wooden interior design elements affect cognitive performance and subjective perceptions.[42] In this experiment, 10 female and 10 male students performed a series of cognitive tasks across four different rooms. These comprised a concrete control room, a room with dark brown wooden surfaces throughout, a room with light brown wooden surfaces throughout, and a Japanese-style room with 50% light brown wood and 50% white-painted wood.

The cognitive performance results were notably strong, with participants demonstrating faster completion times and higher accuracy across all five tests in the three wooden settings compared to the concrete environment.

A survey exploring the subjective opinions of the participants showed that, when given the choice, all of them held a preference for one of the wooden rooms.

The French technological institute for wood industries (FCBA) confirmed these multifaceted positive effects on cognition in a small-scale study in 2021.[43] Compared to a white plasterboard room, a wooden office measurably lowered participants' heart rates, improved subjective feelings of mood and motivation, and produced measurable improvements in work accuracy and speed during a typing test.



The results of the five cognitive performance tasks, with the number of correct responses shown on the left and time to complete on the right. All five tasks showed similar outcome patterns. Adapted from Shen et al. - 2019.[42]

Facilitating attention restoration

For organisations, an obvious candidate for an intervention that increases the naturalness of a space would be the break room or cafeteria. This would support attentional recovery between working hours and enhance employee focus and performance throughout the working day.

The benefits within the workspace itself should not be overlooked, however. At the desk, short breaks of a few minutes or micro-breaks that encourage the eyes to move away from the screen for 10–20 seconds happen all the time, offering brief opportunities for restoration if natural elements are present in the space.

As the research in this segment shows, the presence of wood in the workspace improves concentration, problem-solving speed, and cognitive performance. These findings suggest significant potential for improving outcomes in working and learning environments — spaces that are predominantly designed with conventional materials that do not provide such benefits.

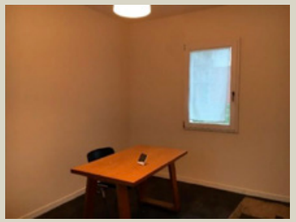


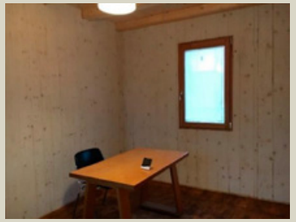
*Offices with wood interior features at the **HasleTre** building in Oslo (NO) by Oslotre Arkitekter*

Break time recovery

The 2022 study at the University of Padova that charted material perception also tested cognitive performance.[44] Two life-sized rooms were constructed to test the influence of a wooden versus a non-wooden environment on attentional capacity of 48 participants and their recovery after a fatiguing task.

The central hypothesis was that wood, due to its inherent naturalness, could positively influence occupants and help restore their cognitive performance. The first test session revealed no significant differences in performance between the two rooms. After the break, however, the influence of the rest environment became clearly apparent.





Participants who took a break in the wood room improved their performance with more correct responses, fewer errors and faster reaction times. Those who rested in the non-wood room showed no benefit from the break, and their performance decreased, presumably due to a continued build-up of fatigue.

Results like these are consistent with Kaplan's attention restoration theory. The naturalness of wooden spaces induces the soft fascination that allows directed attention time to recover, thereby rejuvenating capacity for rapid and accurate task performance.

GROUP Test > Break > Test	**KEY PERFORMANCE CHANGE** from Session 1 to Session 2	**CONCLUSION**
N > W > N	Significant improvement: sensitivity, correct responses, and reaction time improved; errors decreased.	Break in wood room restored attention.
W > W > W	Significant improvement: correct responses and reaction time improved; errors decreased.	Break in wood room restored attention.
N > N > N	No significant improvement in performance.	Break in not-wood room did not restore attention.
W > N > W	Performance degraded: errors increased.	Break in not-wood room did not restore attention.

Overview of changes in participant performance after the break in non-wood (N) and wood (W) rooms. Adapted from Dematté et al. - 2022.[44]



*The breakroom at the **HasleTre** office building in Oslo (NO) by Oslotre Arkitekter. Floor-to-ceiling windows, light timber textures, plants and a panoramic view of the surrounding area all combine into a pleasant and comfortable space for employees to recharge their batteries.*

→ **Recap** Cognitive performance

- **Attention restoration theory** holds that natural environments help restore our capacity to concentrate. Wood brings that **restorative quality** indoors through 'soft fascination' — a gentle, effortless visual interest that lets a tired mind recharge.
- Cognitive tasks performed in rooms with wood are consistently **completed faster** and **more accurately** than in conventional rooms.
- The effect is **strongest during breaks**: resting in a wood-lined room measurably improves recovery and post-break performance, making break rooms and cafeterias a prime opportunity for natural materials.

Concrete, steel, bricks, synthetic panels cannot replicate this performance-boosting effect — making timber a genuine performance advantage for schools, offices, and workplaces.

Nature connection

The evidence linking wood to positive health outcomes is there. The question of why, however, remains to be answered. Why is the perception of wood transformed into beneficial responses by the brain? The answer lies in the way humans have evolved as a species and developed an inherent need for naturalness.

Biophilic design is an approach to architecture and interior design that intentionally incorporates nature and natural elements into built environments. The term comes from 'biophilia', meaning love of life or living systems. This design philosophy recognises that humans have evolved with an innate connection to nature and that we still seek to satisfy this need in our living environment.

Modern humans have evolved as part of nature's systems over a period of 300,000 years. Only in the last couple of centuries have humans moved away from nature into modern-day cities, severing most of that connection along the way.

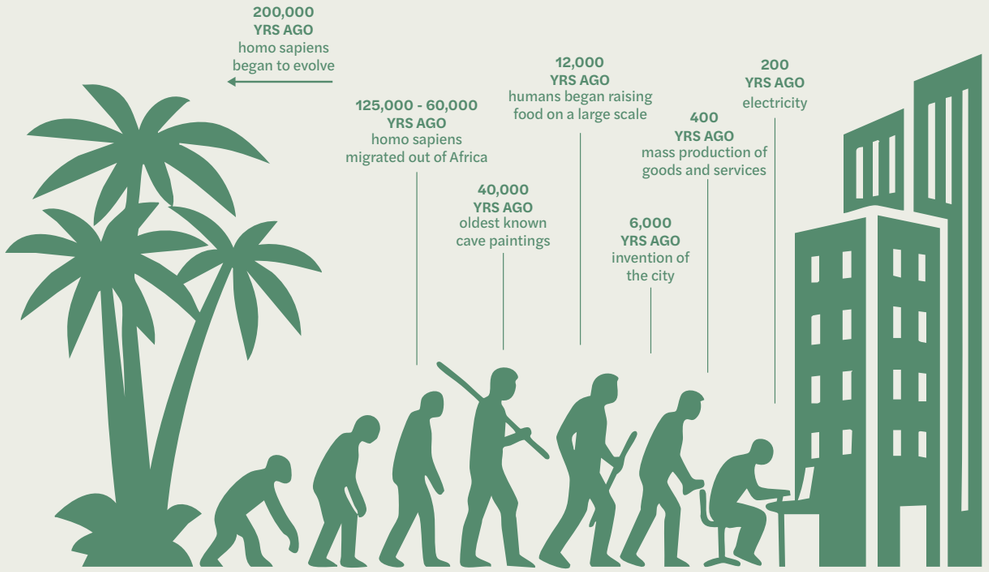


Illustration of the evolution of the human species from nature-based creature to city dweller. Adapted from Stephen Kellert - 2018.[45]

Loss of nature

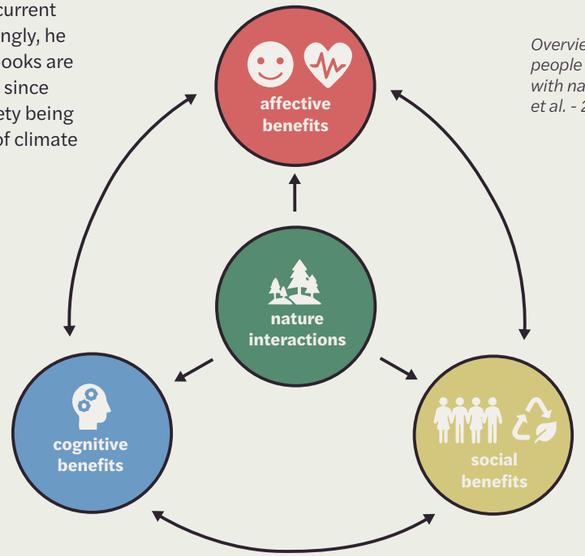
Professor Miles Richardson at the University of Derby has tracked the loss of nature from people's lives in the past 220 years.[47] He studied data on urbanisation, loss of wildlife in neighbourhoods, the decline in parents passing on engagement with nature to their children, and the disappearance of natural words from books between 1800 and 2020.

According to Richardson's research, people's connection to nature has declined by more than 60% since 1800, and this loss of nature awareness is one of the root causes of the current environmental crisis. Interestingly, he reports that nature words in books are actually on the increase again since 1990, likely as a result of society being confronted with the realities of climate change.

Universally beneficial

Marc Berman worked with the Kaplans on attention restoration theory in the past at the University of Chicago. In 2025 he co-authored a 'research dialogue' report that synthesised the latest research that demonstrates the mental health benefits of interactions with natural environments.[46] It discusses numerous indications that even short-term exposure to nature can produce a broad spectrum of benefits across three domains:

- **Affective benefits**: an increase in emotional wellbeing, either by an increase in positive mood or a decrease in negative mood.
- **Cognitive benefits**: increased cognitive functioning or improved performance on cognitive tasks
- **Social benefits**: increases in prosocial or altruistic behavior, for example the willingness to donate or act out of social engagement.



Overview of the ways in which people benefit from interacting with nature. Adapted from Rim et al. - 2025.[46]

Wood connects to nature

Terrapin Bright Green, a leading consultancy in the field of biophilic design, recently published a highly relevant report on how humans perceive and respond to wood in built environments.[48] They reference findings that indicate humans subconsciously distinguish between naturally occurring and human-made objects. Having evolved in nature, humans show a preference for naturally occurring materials. This may explain why wood continues to be preferred in buildings even when many alternative materials are available.

Terrapin explains the nature association and preference for wood with considerable nuance. They conclude that positive responses to wood likely stem from multiple factors working together: association with living things, scent and touch experiences, warm colour perception, and primarily the inherent patterning of wood grain. The brain appears to process wood as a "natural" material despite human manipulation, categorising it differently from synthetic or highly processed materials.

People respond to wood on an intuitive level. It is a recurring theme in research that participants report no particular affinity for wood during interviews, only for the experiment to reveal that their body and brain react positively to it. This indicates that this connection to the material is not a matter of personal taste, but is rooted in shared human biology. As a result, integrating wooden surfaces or elements into spaces benefits all occupants, not only those who consciously prefer its appearance.



Naturalness of materials

A cross-national study conducted in 2015 explored how occupants distinguish between natural and unnatural materials.[49] 187 participants from Finland, Norway, and Slovenia assessed 22 different specimens of building materials, including various forms of wood, stone, brick, engineered wood-based composites, metal, and plastic.

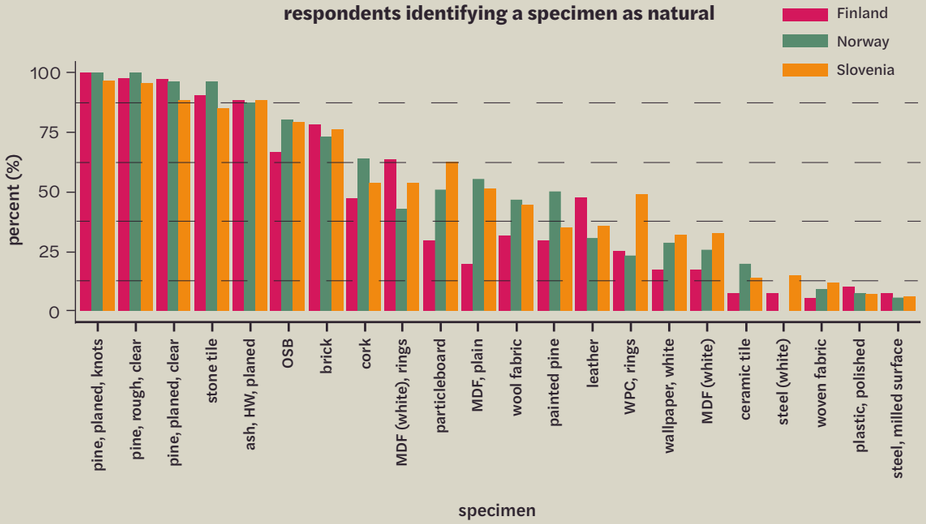
The participants completed a questionnaire that captured their perceptions of a material's naturalness based on the visual appearance of its surface. Beyond the expected result of wood scoring better than plastic and steel, there were a number of interesting takeaways.

There was a high level of **cross-national agreement** across Finland, Norway, and Slovenia regarding which materials are natural.

Participants consistently identified materials with minimal apparent transformation that look **unprocessed** are accepted as natural. Though large, recognisable wood strands and visible grain patterns on some products were perceived as relatively natural as well, despite significant processing.

Features typically viewed as **structural defects**, such as knots in wood, were seen as symbols of authenticity and naturalness.

When designing to foster the **human-nature connection** with stress reduction and wellbeing goals, select materials closer to their raw state.



All material specimens ranked according to the percentage of participants that responded affirmative when asked if the specimen was natural, yes or no. Adapted from Burnard et al. - 2015.[49]



*For the redevelopment of the terminal at **Portland International Airport**, the architects at ZGF worked with biophilic consultancy firm Terrapin on a nature-based strategy to reduce stress for passengers. Daylighting, mass timber features, nature imagery, and interior landscaping connect the passengers to Oregon's natural beauty.*

→ **Recap** Nature connection

- Modern humans evolved over 300,000 years as part of natural systems. Our move into cities is a very recent development, and our biology still appears to carry a **deep-seated need to stay connected to nature**.
- **Biophilic design** intentionally brings nature, including natural materials like wood, into built environments to satisfy that evolved need.
- The brain **processes wood differently** from synthetic materials, classifying it as 'natural' even after significant processing — though the more visible a product's wood grain and texture remain, the more natural it's perceived to be.

People don't just prefer the sight, smell and touch of wood — their bodies and brains respond to it, whether they consciously notice it or not.

The search for a comprehensive understanding

Existing research clearly indicates the potential benefits of building with timber, but the underlying studies often had their limitations. These could include a small number of participants, a singular thematic focus, a lack of direct causality, or an over-dependence on self-reported evidence. The process of establishing a solid and comprehensive understanding of the health impact of wooden spaces remains ongoing, with research initiatives expanding on existing knowledge through new methods and approaches.

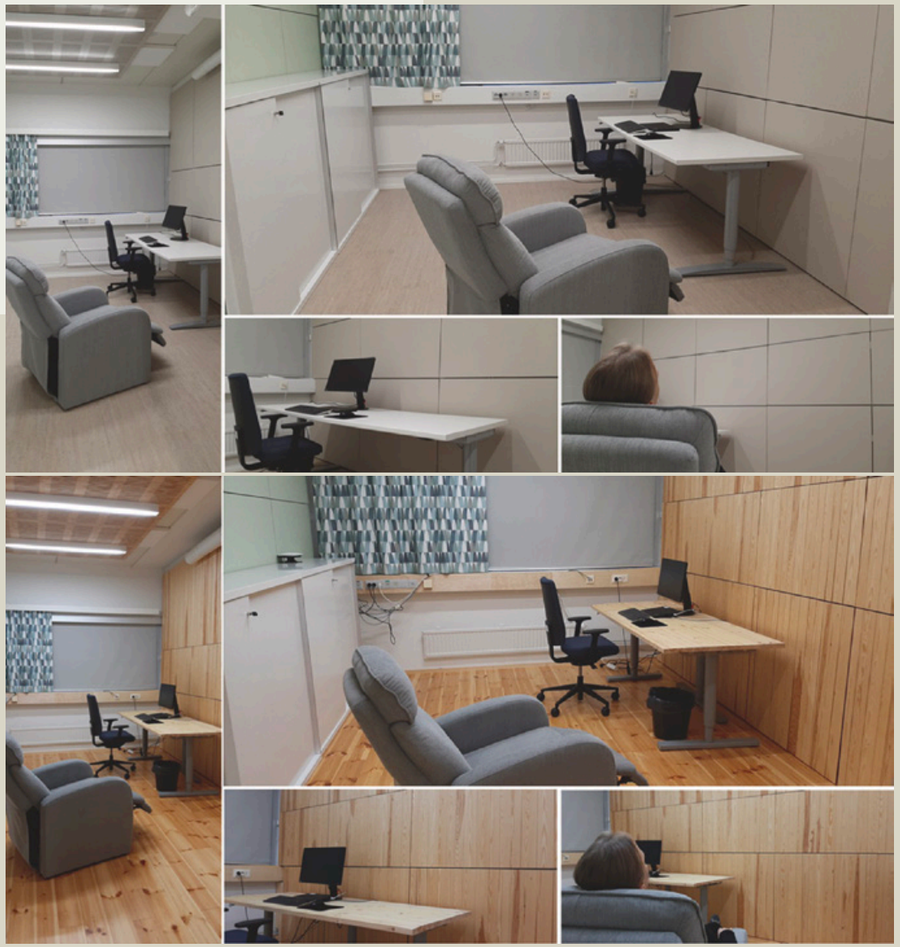
Integrated research

An Australian study from 2024 introduces an innovative and holistic research framework that combines subjective self-reported input with objective biometrics and environmental measurements.[50]

The researchers proposed to combine the following methods of collecting data:

- Survey instruments to capture subjective experiences and perceptions
- Physiological metrics to objectively measure stress and health status
- Continuous monitoring of the physical environment

The idea is that synthesising and connecting the results of the various types of data can lead to new insights on the complexity of how people experience place and space. This preliminary work provides a valuable foundation for future research that aims to understand the multifaceted benefits of wooden buildings.



Two test rooms used in the mixed method study. Neutral colours and plasterboard walls above, a variety of wood surfaces below.

Positive alertness

A 2024 study in Finland illustrates how this mixed method approach can be productive.[51] Researchers investigated whether using natural materials like wood in an office can actively reduce stress and help people recover from mental fatigue. The experiment took place in two office rooms that were identical in size and layout. The only difference was the surface materials used: one had grey plasterboard and ceiling panels and the other featured pinewood surfaces.

A total of 61 participants went through a 45-minute session designed to simulate a typical work-and-break cycle. The methods for measuring the effects on the participants ranged from self-reporting through questionnaires to quantifiable metrics such as heart rate variability, which indicates activity of the sympathetic nervous system, and skin conductance, which indicates physiological arousal.

Participants reported positive psychological effects in the wooden room, such as feeling less anxiety and experiencing fewer negative emotions compared to the control room.

The expectation among the researchers was that the wooden room would produce a calming physiological effect. Surprisingly, the results showed increased sympathetic activity, which occurs when the body is preparing itself for action. This contradicted with the interviews afterwards, where participants stated they were feeling more at ease in the wooden room.

The additional insight and context gained from connecting different types of data enabled the researchers to conclude that the higher arousal actually indicated a beneficial effect: a state of positive alertness.

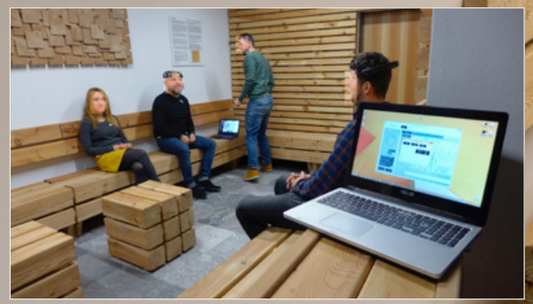
Broad spectrum analysis

Another study that adopted a broader, more wide-ranging approach took place in 2019 in the waiting room of the National Centre for Oncology in Slovakia.[52] A notably impersonal space that dated from the socialist era and quite a serious setting where people deal with the devastating and depressing consequences of cancer.

The area was renovated using natural wood elements including solid pine wood for wall and ceiling paneling and larch timber for seating. A multi-disciplinary methodology was employed to measure the impact of this refreshed environment on volunteer participants.

Physiological responses of 50 volunteers were monitored through a series of biometrics, including brain activity using EEG, heart rate and HRV, respiration using ECG, blood pressure and cortisol levels. In addition, emotional responses were analysed by scanning facial expressions, surfaces were tested for microbes, and air quality was checked by measuring the concentration of VOCs.

The findings provided multi-faceted evidence indicating that the wood-renovated healthcare environment had an indoor air quality that was hygienically viable and that it contributed positively to human wellbeing, in a space where such a benefit is especially welcome.



Volunteer participants during the study

*Renovated waiting room at the **National Oncology Centre in Bratislava** (SK)*

→ **Recap** New research

- Newer studies are combining multiple types of data — self-reported experience, biometrics, and environmental monitoring — for a **more complete picture** of how wood affects people.
- This **integrated approach** is where the field is heading: connecting what people say they feel with what their bodies are actually doing produces more reliable conclusions.
- Studies like these bring the transition to on-site research closer by developing a more integrated and robust **methodology**.

No individual study proves it alone, but the sheer volume and consistency of the evidence points in one direction: wooden buildings create healthier environments.

3 Making the case for timber

Quantifying benefits to humans and organisations expands the case for timber beyond environmental sustainability. It establishes a clear link between building materials and benefits for comfort and health, which in turn contribute to employee wellbeing and productivity, and to improved quality in educational and healthcare spaces.

This chapter explores what the evidence-based benefits mean in practice for the industry stakeholders who commission, fund, design, and build. First, we look at shifting consumer preferences and how health is valued in building certifications. Then we examine the workplace, where employee wellbeing connects directly to organisational performance. After a discussion of the regulatory and policy landscape we close with some practical guidance for architects and engineers on how to use timber in ways that genuinely deliver on its health potential.

*The lobby at **Credit Valley Hospital** in Mississauga, Ontario (CA) by Farrow Partners. Massive, tree-like timber columns branch out from a floorspace that is divided by internal landscaping. The courtyard-like interior offers both small rest areas and large spaces that expand to the roof and fill with daylight.*

WGBC framework

In 2020, the World Green Building Council launched the Health and Wellbeing Framework aimed at extending the sustainability concept beyond emissions alone, to human health, equity, and resilience.[53] Through six headline principles, the framework provides detailed information on the key aspects of human health, wellbeing and quality of life that relate to the built environment sector.



As findings throughout this report have demonstrated, building with timber was found to relate directly to four of these principles:

- **Take Climate Action**: timber is the primary low-impact, fossil-free, renewable building material.
- **Protect Health**: both in reducing negative health effects and producing benefits, timber comes out on top when compared to conventional materials.
- **Prioritise Comfort**: as a natural material, timber adapts to indoor climate fluctuations, maintaining consistent comfort levels for a building's occupants.
- **Harmony with Nature**: wood in spaces reconnects occupants to their natural origins, creating associations of warmth, wellbeing, and authenticity.

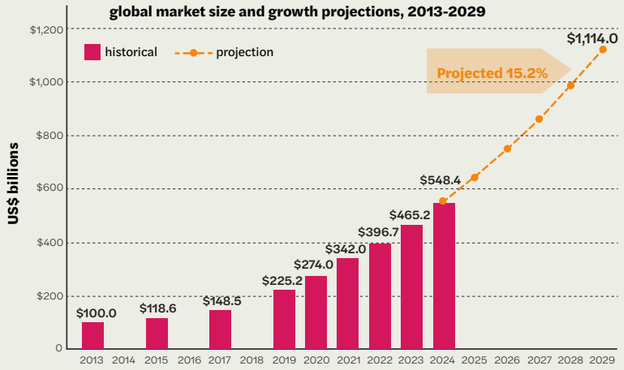
Healthy buildings as an industry

The building sector is witnessing a fundamental shift in occupant preferences towards healthier indoor environments. This is translating into market demand, with buyers and tenants seeking healthy residences and companies seeking office spaces that demonstrate a commitment to employee health and wellbeing. Timber can play a unique role in meeting this demand due to both the material properties and the biophilic aspects.

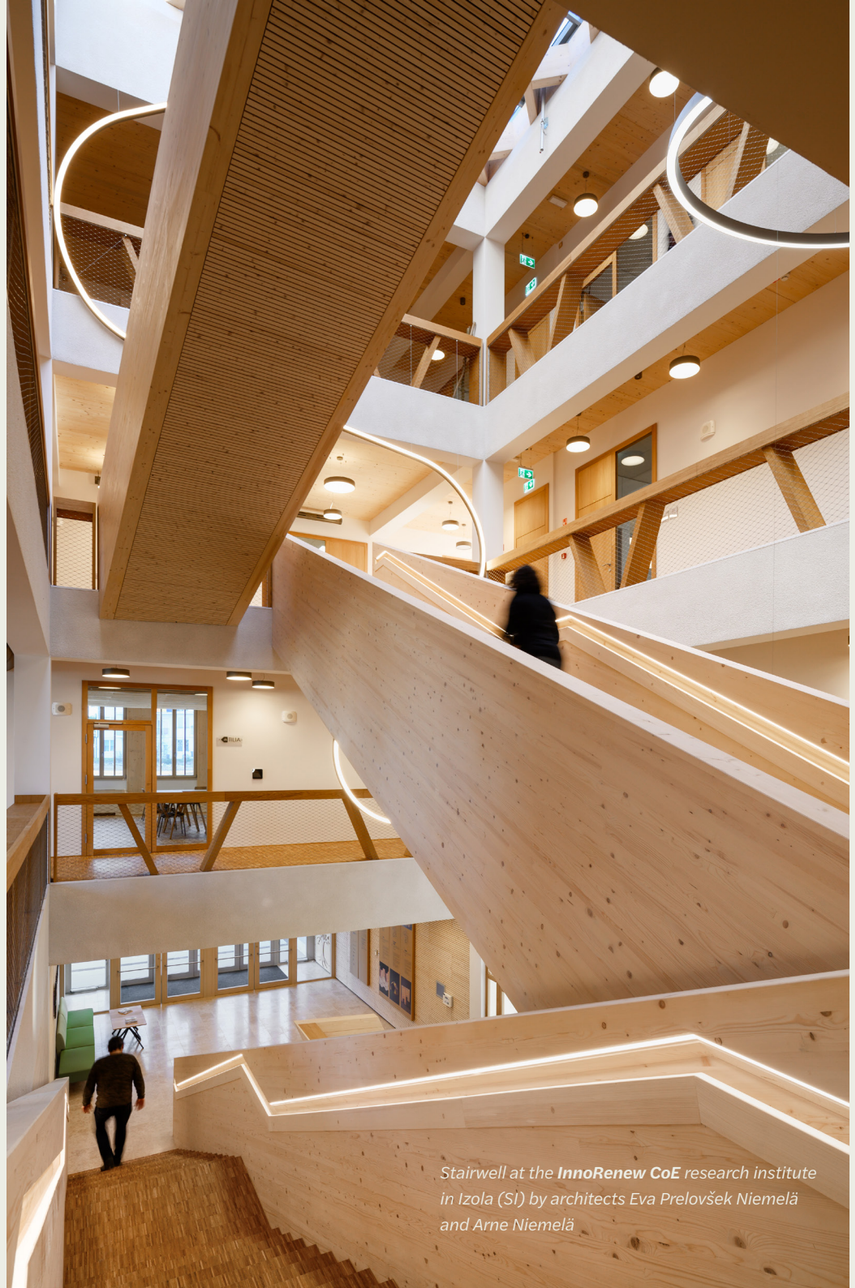
Consumer shift

Non-profit organisation Global Wellness Institute tracks worldwide expenditures on the construction of residential and commercial/institutional properties that incorporate intentional health elements in their design, materials, and building. They report that health-focused real estate not only improves occupant wellbeing but also delivers measurable financial returns.[54]

Developers, investors, owners, consumers, and occupants have demonstrated a strong interest in healthy real estate and the willingness to pay for it. Health-focused residential properties can command a price premium of 10–25%, while commercial buildings have demonstrated a 4.4–7.7% rental premium per square foot.



Upward trend in the market for health oriented building design. Adapted from GWI - 2025.[54]



*Stairwell at the **InnoRenew CoE** research institute in Izola (SI) by architects Eva Prelovšek Niemelä and Arne Niemelä*

Certifications

In today's climate-aware society, an organisation's public profile and corporate image benefits from demonstrating compliance with established green building certification programmes such as WELL, LEED, BREEAM, and the Living Building Challenge. The same goes for timber supply-chain certifications, such as FSC and PEFC.

The **WELL Building Standard** views buildings as intervention tools for promoting health.[55] It specifically focuses on measuring and certifying features that impact human health and wellbeing through air, water, nourishment, light, fitness, comfort and mind, including many areas in which timber buildings can demonstrate strong performance. Their v2 standards include criteria addressing thermal comfort, physical activity, mental health, and the elimination of hazardous building materials.

Other well-established green building certifications like **LEED** and **BREEAM** have been shifting toward a more holistic emphasis on human health, adding criteria related to indoor environments and occupant wellbeing.[56]

The 'living systems' approach of the **Living Building Challenge** considers buildings as the starting point for establishing far-reaching health outcomes at the community, city, and regional level. Living Future's building certification subjects projects to a rigorous, full-spectrum screening process, including a healthy materials scan, a prohibition on Red List substances, and proof of a year-long in-use performance record.

Living Future's broad-spectrum view of health encompasses not only physical, mental, and social health, but also equality, universal access, and ecological health through biodiversity. By raising the bar high, all fully certified Living Buildings represent outstanding examples of a truly regenerative built environment.

*The **Municipal Yard Nieuwkoop** (NL) by ORGA architect features a 22 meter wide area for vehicle storage. To allow the wide variety of vehicles to freely move around, a sawtooth roof structure was designed out of CLT that spans the entire space without the need for columns. This historical roof type is highly suited for sustainable design for its ability to both maximise natural light and host angled solar panels.*

ESG alignment

For organisations, building with timber and integrating wood in the interior design contributes to an environmentally responsible corporate and brand image. For this reason, institutional investors increasingly use ESG data to identify opportunities that provide return in the long run.



Notably, timber construction and wood interiors address all three pillars of the Environmental, Social, and Governance (ESG) framework in documented, measurable ways:

- **Environmental**: carbon reduction, renewable sourcing, and certified supply chains.
- **Social**: scientifically demonstrated health, wellbeing, and productivity benefits for building occupants.
- **Governance**: alignment with major reporting frameworks and certification systems and proactive alignment with tightening embodied carbon regulations.

The evidence base is strongest on the environmental side, growing rapidly on the social side (to which this report aims to contribute), and increasingly structured on the governance side as frameworks like Built by Nature's Principles of Responsible Timber Construction gain ground.[57]

Nature in the workplace

In recent decades, there has been growing recognition of the importance of healthy working conditions, especially the need to improve mental health and prevent stress and burn-out. Employers have started to understand the costs that result from low engagement, absenteeism and presenteeism.

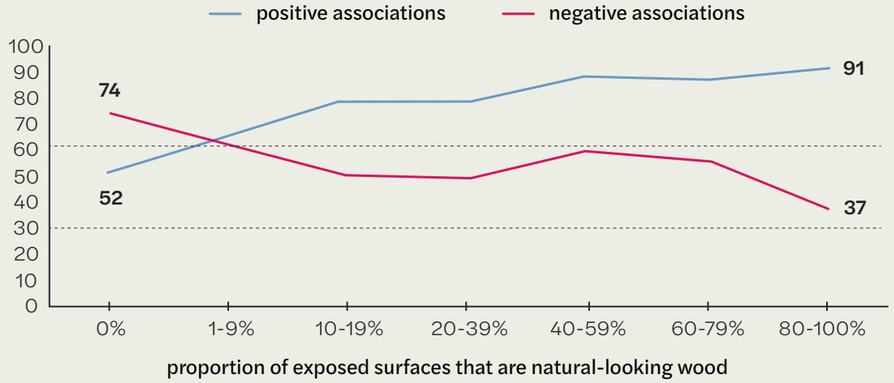
Workplace survey

The 2015 Human Spaces report surveyed 7,600 office workers from 16 countries across the world to evaluate the relationship between physical work environments, psychological wellbeing, and employee expectations.[58]

Their goal was to quantify the benefits of nature's presence in buildings on three key organisational outcomes: wellbeing, productivity, and creativity. The study showed that the employees who work in an environment with natural elements report a 15% higher level of wellbeing, a 6% higher level of productivity, and a 15% higher level of creativity than those who worked in a space devoid of nature.

Human Spaces also discovered that a third of the respondents were affected by workplace design when choosing to work for a company, which emphasizes the influence of the work environment on an organisation's appeal and its contribution to the retention of staff and reducing employee turnover.

Major tech companies recognised this and embraced biophilic design as a strategic tool for building healthier, more appealing workplaces in their efforts to attract skilled employees. These leading organisations, generating billions in annual revenue and employing tens of thousands, have concluded that nature connection, such as the presence of wood, represents the right investment for maintaining a competitive edge.



The survey among a 1,000 Australian office workers showed a positive relation between the amount of wood features in their workspace and workplace satisfaction. Adapted from Pollinate - 2018.[59]

Connecting the natural workplace to financial outcomes

Terrapin Bright Green examined the economic value of introducing nature into buildings in their 2023 report 'The Economics of Biophilia'.[60] They argue that the built environment must meet both basic needs like shelter and sunlight, and more complex requirements such as attention restoration, social connection, and a sense of security.

When buildings fail to provide these essentials, the costs can be substantial, though not always immediately apparent. So how do organisations and communities benefit this? The research Terrapin collected shows that enhancing the naturalness of indoor environments by incorporating biophilic elements delivers measurable benefits to health, cognitive performance, and emotional wellbeing.

In turn, these improvements can lead directly and indirectly to financial value, for instance through increased productivity, faster patient recovery, enhanced learning outcomes, and stronger customer engagement.

SECTOR	**HEALTH & WELLBEING**	**FINANCIAL IMPACTS** DIRECT	**FINANCIAL IMPACTS** INDIRECT
OFFICES	presenteeism, performance, productivity	absenteeism, staff retention; lease rate, churn	talent acquisition health claims, employee satisfaction
EDUCATION	attention, learning rate	absenteeism, test scores	graduation rates
RETAIL	customer attention, brand perception	hedonic value, sales; staff retention	dwell time, return patronage, social media attention
HEALTHCARE	healing rate, analgesic intake	patient turnover; staff retention	visitor perception
HOSPITALITY	staff performance, perception of place	average daily room rate (ADR, RevPAR)	employee satisfaction, brand loyalty, social media attention, total revenue per available room (TRevPAR)
COMMUNITIES	perception of safety, crime rate;overall public health	tourism; crime rate	investment attraction, migration; real estate value, tax base; climate change adaptability, resilience, equity; incarceration rate

This table from 'The Economics of Biophilia' provides an overview of the potential impact across different sectors.



*The **Wildlife Shelter Avolare** in Doorwerth (NL) by ORGA architect is natural architecture in both form and function. The timber building lets animal life recover to be released back into the wild and supports the wellbeing of human employees with biophilic workspaces.*

Improving public health through policy

Materials and design features in buildings are not neutral; they are clear determinants of health. Yet, despite the evidence, the health potential of building materials remains largely unaddressed in public policy. Government organisations and policymakers are particularly well placed to address this, as they fund research, update building codes, define procurement standards, and commission public buildings.

Evidence-based policy

Decisions about which materials are used in buildings have historically been driven by structural performance, fire safety, and cost. Health effects on occupants have received far less attention and the focus is often aimed at harm prevention, rather than promoting health and wellbeing.

But this is beginning to change. Research across disciplines that range from neuroscience and environmental psychology to architecture and public health is producing evidence that the materials surrounding occupants indoors have a measurable effect on how they feel, think, and perform.

At the same time, virtually every one of the studies used in this report concludes that additional research is required to further understand the results and move forward with practical implementation.

Because no single sector can fully unlock these health benefits from within their silo, the government is well placed to act as a convener, bringing professionals together across disciplines. This should really start with developing the methodology needed to consistently evaluate real occupant experience.

Opportunities

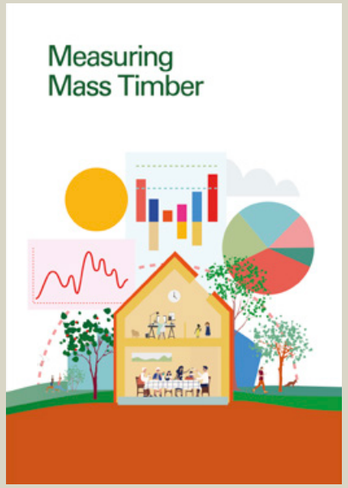
Public health would benefit directly from governments investing in high-quality research and grounding their material policies in robust, peer-reviewed evidence. There are several opportunities for government organisations and policymakers to accelerate this type of collaboration:

1. **Funding interdisciplinary research programmes** that require academic, design, and industry partners to work together.

2. **Developing the methodology for, and mandating post-occupancy evaluation** of public buildings. Create feedback loops between how buildings are designed and how they perform for the people who use them.

3. **Establishing knowledge-sharing platforms** where findings are translated into practical guidance for designers and contractors.

4. **Integrating knowledge about timber's health benefits into these national and international rulesets** for the built environment could significantly expand their use in construction and their effect on everyday life.



A research project in the UK that demonstrated what productive cross-sector coordination can look like is *Measuring Mass Timber*.[61] It brought together architects at dRMM, scientists from Edinburgh Napier University, funding from non-profit organisations, and a diverse advisory group of industry stakeholders.

This collaboration produced the first large-scale Building Performance Evaluation of in-use mass timber buildings. Whole life carbon analysis and measured environmental data were combined with occupant experience surveys.

Criteria for government building projects

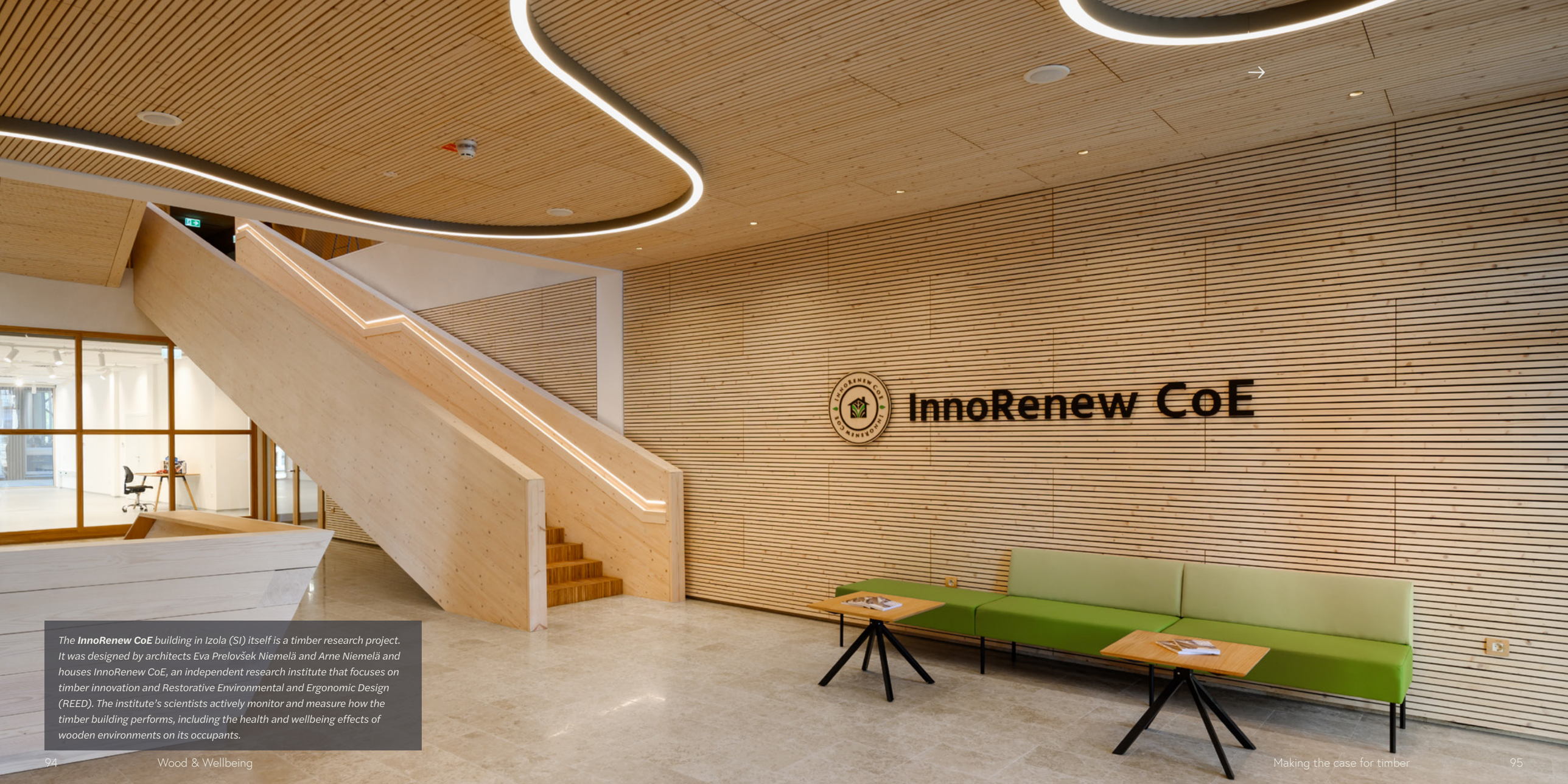
Governments are among the largest owners and procurers of buildings in any country. By adjusting the criteria used to award design or construction contracts, governments can directly drive the adoption of healthier building practices, including the use of timber.

The scale of potential impact is significant, as government commissioned buildings make up between 15% and 30% of all building construction, depending on the country. However, while carbon impact and energy performance are increasingly common criteria, health is rarely included in the process. Public procurement with clear criteria for healthy building materials can play a crucial role in creating incentives for builders and developers.

Driven by government incentive, the economic value of healthy building expertise will permeate the construction and real estate sector, prompting developers, architects, engineers, and suppliers to follow suit.

In order to make health outcomes part of the procurement practice, governments can include occupant health and wellbeing as weighted criteria in tender evaluations for new public buildings:

- Require tender submissions to demonstrate how the building and its materials **protect and promote the wellbeing** of the occupants.
- Setting **targets for biophilic design features**, such as exposed timber, in schools, healthcare facilities, and government offices would deliver measurable benefits to public health.
- By requiring **post-occupancy evaluation of health outcomes** as a standard deliverable for all publicly funded construction projects, each new building would contribute further insight and expand the evidence base.



*The **InnoRenew CoE** building in Izola (SI) itself is a timber research project. It was designed by architects Eva Prelovšek Niemelä and Arne Niemelä and houses InnoRenew CoE, an independent research institute that focuses on timber innovation and Restorative Environmental and Ergonomic Design (REED). The institute's scientists actively monitor and measure how the timber building performs, including the health and wellbeing effects of wooden environments on its occupants.*

Creating timber architecture

With industry norms gradually shifting towards the inclusion of health standards, nature is increasingly seen as a source of inspiration for materials, mechanisms, and aesthetics. Designing and engineering buildings with timber is increasingly recognised as a key instrument in that pursuit.

As a result, developing credible expertise in timber construction is a strategic opportunity for architects. They can establish themselves at the forefront of a rapidly evolving market, while those who delay risk falling behind as client expectations shift and project briefs increasingly reflect sustainability targets.

While it does takes some knowledge and experience to make optimal use of wood as a building material, some basic principles will go a long way towards creating healthy spaces. Most importantly, take into account that the visual experience of wood features and the resulting associations with nature are the most powerful components of the positive health outcomes. Painting over wood with opaque paint or covering it with wallpaper or gypsum board eliminates these visual benefits entirely. Instead, there is a wide variety of transparent coatings and finishings, ranging from natural oil, resin or wax to synthetic lacquer or varnish.

This section provides tips and insights on how to get the most health and aesthetic effect out of these natural materials. Some of these guidelines stem from research, but most of it is accumulated knowledge from designing and building timber architecture for 20+ years.

*The teachers lounge at primary school **De Verwondering** in Almere by ORGA architect*

Quantity

Indoor spaces with a moderate proportion of wood surfaces generated the strongest positive responses. Very low and very high levels produced a weaker effect, or in some cases a negative one. For optimal health outcomes, designers should aim for a considered composition of surfaces rather than simply meeting a quantity target, taking into account the function of the space, all objects that it will contain and the type of occupants that will be using it.

Biobased performance

The combined effect of natural materials, often in a layered assembly, makes timber buildings healthy and comfortable. Always consider the performance of a building element in its entirety to safeguard this synergetic effect, which includes being careful with paints, coatings, or films that could compromise it.

Variety

The variety of wood surfaces can be equally important to quantity. Design decisions regarding the different colours and textures or application across floors, walls, and ceilings also have a considerable impact on the way occupants perceive its presence. In general, mixing wood colour and textures in a moderate amount is experienced as pleasant.

Zoning

Several studies recommend using a zoning approach when choosing wood surfaces, particularly in healthcare settings[62] or schools. Both environments where the positive health effects of wood carry great potential, but hygiene is frequently cited as a deterrent for incorporating natural materials.

In complex or multi-use building designs, assigning zones for specific types or methods of wood application that meet the functions or demands of those spaces can be an effective strategy. High-touch surfaces or spaces that have special hygiene requirements and require intense cleaning may warrant additional finish or treatment.

The effect of coatings

Factors beyond health and comfort, such as fire safety, hygiene demands, and aesthetics, can make it necessary to add finishings or coatings to a wood surface. But there is a trade off here, as applying these type of products can inadvertently compromise some of the health benefits untreated wood provides.

Tactile experience

Wooden handles and railings are valued for their warm tactile quality. The low thermal conductivity of wood draws heat away from the skin much slower than metal or plastic. However, when film-forming lacquers such as polyurethane are applied, the quality of the tactile connection diminishes and the wood starts to resemble smooth plastic. Natural oils and waxes are excellent alternatives as they are absorbed into the wood cells instead, keeping the texture and thermal qualities intact.

Wood scent

The scent of wood is generally experienced as pleasant and has been shown to have a calming effect. This can only be achieved by exposed and untreated wood, as coatings can block wood scents from leaving the material.

An interesting and perhaps surprising side note: the perception of scent is strongly influenced by what we see.[63] Subconsciously, the brain makes connections between different sensory experiences. For instance, a wood scent is perceived as more pleasant when the wood itself is visible. This is a strong argument for keeping wooden elements visible, even when they have been treated.

Coatings and hygiene

Harmful microbes and viruses have a harder time surviving on an untreated wooden surface. While the effectiveness of the protective properties depends on the type of wood and pathogen, a finishing or coating could hinder the material's natural hygienic performance. For example, lacquers and varnishes that form a thin film on the surface prevent all three protective mechanisms: extractives cannot reach the bacteria, moisture is blocked from being absorbed and the surface structure no longer porous.

*School building **De Verwondering** in Almere (NL) by ORGA architect is a prime example of biophilic architecture. The design features, the educational program, and the selection of biobased materials that make up the building are all inspired by nature, with the goal of providing a healthy learning environment. The hybrid CLT/timber frame building received the Stephen Kellert Biophilic Design Award in 2023, awarded by Living Future.*

Optimising timber design

By creatively and purposefully aligning timber materials with the form, feel and function that works best for its intended occupants, a building transforms from a passive structure into an active contributor to human wellbeing.

For optimal health outcomes from the natural properties of timber, keep these aspects in mind:

- Ensure the **wood grain remains visible** and has a sizeable presence in the space.
- Prioritise **breathable, non-film-forming finishes** to preserve tactile and antibacterial benefits.
- **Avoid gypsum and plastics** on wooden substrates: clay or lime plaster is an excellent alternative.
- Always look for the possibility of an enhanced **combined effect** with other biobased materials.

***House in a Hill** in Utrechtse Heuvelrug (NL) by ORGA architect*

→ **Recap** Trends and guidelines

- **Health-focused buildings** are no longer a niche: buyers and tenants pay measurable premiums for them, and **certifications** like WELL, LBC, LEED, and BREEAM increasingly reward timber's health performance.
- In the workplace, natural materials like wood are linked to **higher employee wellbeing, productivity, and creativity** — turning biophilic design into a retention and recruitment advantage, not just an aesthetic one.
- Timber's health potential is still largely missing from **building codes and procurement standards**, leaving governments — major builders and regulators in their own right — well placed to close that gap.
- Getting the full benefit from timber takes **deliberate design choices**: the right amount and variety of exposed wood, smart zoning, and finishes that don't compromise its natural properties.

Timber checks every box at once: environmental, financial, and human. Making it one of the few building materials where doing right by the planet and doing right by people are the same decision.



***De Verwondering** in Almere by ORGA architect*

Current limitations

The evidence base for the health benefits of building with timber is rich, wide-ranging, and growing. But there are some caveats that the researchers themselves are the first to acknowledge.

- Controlled laboratory conditions are artificial settings. However carefully designed, these can only partially replicate the complexity of real-world experience.
- Small participant groups do not always represent the full diversity of building users.
- Self-reported data can provide valuable insight into how people feel but cannot always be correlated with objective physiological outcomes.

These are not reasons to doubt the direction of the findings, as the consistency across so many independent studies carries weight and meaning. At the same time, evidence for positive health effects from conventional building materials seems to be absent. Building materials that currently see widespread use are rarely judged on health impact, only on costs.

Despite some of the limitations mentioned, a clear link between wood and health has been established. These make a compelling case for a new generation of research. One that takes the promising findings gathered here and tests them at greater scale, in more diverse conditions, and with methods better equipped to reflect real-world experience.

Future research

The most valuable next step is developing more robust methodology for in-lab experiments which can be transferred reliably to working on location. That will enable research to move out of the laboratory and into real timber buildings that are already in use. Examining how occupants actually feel, perform, and recover over weeks, months, and years, rather than in brief, controlled sessions, would be highly valuable.

Topics such as the symbiotic relation between timber and other biobased materials and the way wood is perceived across geographical regions, different cultures, or varying age groups are relatively unexplored and might provide new insights.

A trend that is already ongoing is the adoption of integrated, mixed-method approaches that combine subjective self-reporting, objective biometrics, and continuous monitoring of the physical environment. Connecting these different data streams can reveal effects that no method would detect alone.

Building a larger, more reliable evidence base of this kind will further enable translating what research already shows into the building codes, procurement standards, and design guidelines. That will allow timber research to move forward from promising findings to actual application in buildings that meaningfully improve the lives of the people inside them.



Physical comfort

Buildings built from timber and other natural materials stay at a **comfortable temperature** year-round, reducing or even removing reliance on mechanical heating or cooling.

Unlike mechanical ventilation, timber **regulates indoor humidity** passively — with no energy use, no maintenance, and no emissions required to do that job.

Clean indoor air

Emission of natural VOCs from timber **declines over time** and does **not cause any major health issues**. Research links natural wood VOCs to **stress reducing effects** on building occupants.

Negative health impact from synthetic VOCs in wood products **can be avoided by choosing the right product**, free of formaldehyde-based adhesives.

Healthcare spaces

Wood is **not a hygiene compromise** when designing healthcare buildings. It is the better-performing choice with a surface that **resists pathogens** and has a **stress-reducing effect** on both patients and employees.

The often stressful spaces in healthcare can benefit from more naturalness. Cleaning requirements in high-risk areas can be met using transparent coatings, without compromising the **beneficial visual presence**.

Workplace upgrade

Wood features in a space trigger an automatic, unconscious **calming effect**. This helps people to avoid stress while working, recover faster during a break and rest better at night.

Cognitive performance in rooms with wood features is better and so is the ability to **restore focus** — making timber a genuine performance advantage for schools, offices, and other places of work.

Essential health benefits of timber

Timber is a low impact, high performance building material, it presents financial outcomes for organisations through employee wellbeing and productivity, and produces universal health benefits from re-establishing our connection to nature.

Universal appeal

People do not just **prefer the sight, smell and touch** of wood — their bodies and brains respond to it, whether they consciously notice it or not, making its benefits **universal**.

This positive response to wood goes **beyond aesthetic preference** — its warmth, grain, texture, and scent **engage the senses** in ways conventional building materials simply don't.

Concluding remarks

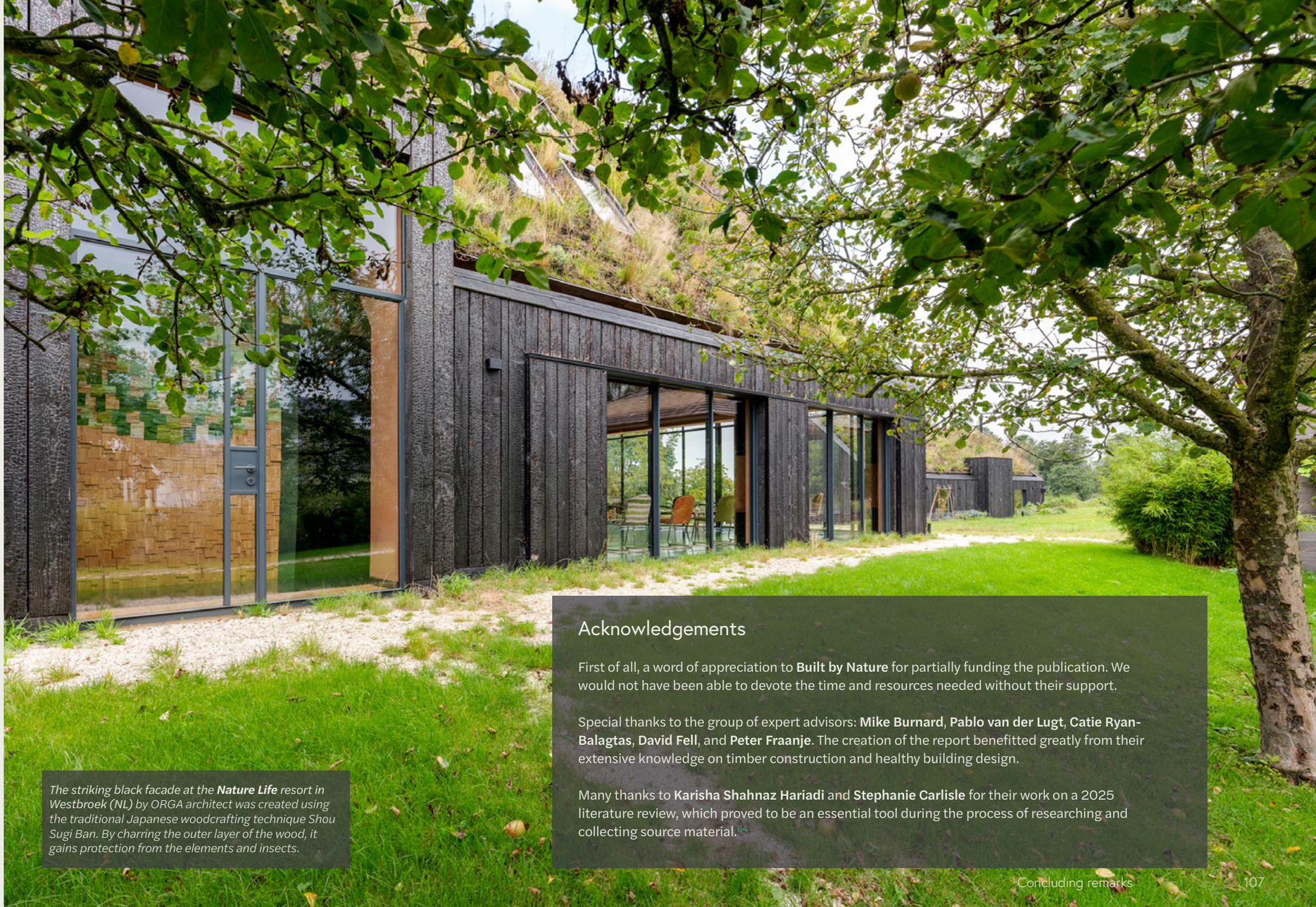
Measured against conventional construction materials on environmental terms alone, the case for timber is already compelling. The findings in this report make it clear that the full argument for timber is yet to be made. The health benefits documented here represent a dimension of timber's value that has been largely invisible in the sustainability conversation until now.

That conversation is changing, and it needs to change further. After all, a building that performs well on energy metrics while making its occupants anxious, unfocused, or unwell is not a sustainable building. Truly sustainable architecture includes what a building gives to the people inside it, not only what it takes from the planet.

The research is consistent: exposure to natural materials such as wood, produces measurable benefits that synthetic alternatives simply cannot replicate. And critically, wooden surfaces can deliver something close to the restorative effects of outdoor nature exposure in urban environments where access to actual nature is mostly constrained.

Perhaps the most important shift implied by the evidence takes place on a philosophical level. Human-centred design, for all its virtues, has tended to place people at the apex of the design equation. Life-centred design asks us to reposition ourselves within nature's living systems, not above them. Timber, sourced responsibly and used well, is a material that grows from the earth, stores life within its structure, and returns to living cycles at the end of its use. To build with it is to participate in the planet's ecology rather than merely extract from it.

Aligning the spaces where we live and work with the natural world is an element that's currently missing. It offers an untapped potential for creating health in our daily lives — one that we can no longer afford to leave unused.



*The striking black facade at the **Nature Life** resort in Westbroek (NL) by ORGA architect was created using the traditional Japanese woodcrafting technique Shou Sugi Ban. By charring the outer layer of the wood, it gains protection from the elements and insects.*

Acknowledgements

First of all, a word of appreciation to **Built by Nature** for partially funding the publication. We would not have been able to devote the time and resources needed without their support.

Special thanks to the group of expert advisors: **Mike Burnard**, **Pablo van der Lugt**, **Catie Ryan-Balagtas**, **David Fell**, and **Peter Fraanje**. The creation of the report benefitted greatly from their extensive knowledge on timber construction and healthy building design.

Many thanks to **Karisha Shahnaz Hariadi** and **Stephanie Carlisle** for their work on a 2025 literature review, which proved to be an essential tool during the process of researching and collecting source material.[84]

Recommended reading

For readers who are eager to learn more we've put together a list of recent sources that are well suited to continue exploring the topic of health and timber buildings. Some of these are featured in the report, but not all.

Reports & whitepapers

(most recent first)

Systematic study of scientific evidence on the health impacts of wood in indoor environments
Renate Weisböck-Erdheim, Nathalie Gerner, and Arnulf Josef Hartl, *Holz im Innenraum und Gesundheit: Was Studien zeigen.* (Paracelsus Medizinische Privatuniversität / Institut für Ökomedizin, 2026).

Designing healthcare spaces using wood
White Arkitekter, ed., *Wood for Health: A Guide to Using More Wood in Healthcare Buildings* (Wood for Health / ERA-NET ForestValue, 2025).

Comparative study of five in-use timber buildings in the UK
Kat Scott and Finbar Charleson, *Measuring Mass Timber: Deriving a mass timber whole life carbon & quality of life method by evaluating five mass timber UK buildings* (dRMM, 2025).

Case studies of biophilic timber buildings in North-America
Bill Browning and Catie Ryan, *Biophilic Design with Wood in British Columbia* (Terrapin Bright Green / Forestry Innovation Investment, 2024).

Mass timber in school design
Mithun. *Mass Timber Schools: Building for Wellness.* (Mithun Research + Development, 2022).

Detailed exploration of the human response to wood
Bill Browning, Catie Ryan, and Joseph DeMarco, *The Nature of Wood* (Terrapin Bright Green, 2022)

Report on the benefits of timber buildings for organisations
Graham Lowe. Wood, *Well-being and Performance: The Human and Organizational Benefits of Wood Buildings.* (Forestry Innovation Investment, 2020).

White paper exploring the benefits of timber buildings
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Broad spectrum industry report on the benefits of timber
Ed Suttie, *The Role of Wood in Healthy Buildings*. TRADA Briefing. (TRADA, 2019).

Literature reviews

These review articles can be used to supplement the list of sources on the endnotes pages below:

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*Instead of a conventional concrete base, the lightweight timber **Forest Houses** at the Huis te Maarn estate by ORGA architect rest on ground screws to minimise impact on the forest ecosystem.*

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Photo credits

p. 1 Close-up of facade of affordable housing project by ORGA architect. Photography by Niek van Engelen.

p. 2-3 Wildlife shelter Avolare by ORGA architect. Photography by Ruben Visser.

p. 5 Dark timber cladding. Photography by Anton Darius, Unsplash.

p. 6 Hong Kong, viewed from the Victoria Peak vantage point. Photography by Jacob Dyer, Unsplash.

p. 7 Forest House by ORGA architect. Courtesy of Bouwbedrijf Van Engen. Photography by Robert Koelewijn.

p. 8-9 Close-up of the interior of the Hollow pavilion by Katie Paterson and Zeller & Moye architects. Photography by Max McClure.

p. 12 Timber house by ORGA architect. Courtesy of Bouwbedrijf Van Engen. Photography by Robert Koelewijn.

p. 13 Close up of a timber frame wall during construction. Photography by ORGA architect.

p. 16-17 Construction of the Wiltensacker country house. Photography by ORGA architect.

p. 18 Placement of prefab straw wall panels. Courtesy of EcoCocon®.

p. 20 Building 2226 by Baumschlager Eberle Architekten. Photography by Eduard Hueber

p. 21 ONO building by OZ Architects. Courtesy of OZ Architects and Synchroon. Artist impression by WAX.

p. 22-23 Nature Cemetery Slangenburg by Giesen Architectuur. Courtesy of Giesen Architectuur BV.

p. 24-25 Einfach Bauen by Florian Nagler Arkitekter, Thomas Auer and TUM. Photography by Sebastian Schels.

p. 26-27 Construction of the Wiltensacker country house. Photography by ORGA architect.

p. 29 Dark timber cladding. Photography by Ryunosuke Kikuno, Unsplash.

p. 30-31 Timber construction in Callantsoog. Photography by ORGA architect.

p. 32-33 Timber ceiling. Photography by ORGA architect.

p. 35 Tree at Fort de Chambly, QC, Canada. Photography by Abe B. Ryokan, Unsplash.

p. 36-37 CLT construction of residence in Harfsen. Photography by ORGA architect.

p. 39 CLT construction of HasleTre building. Courtesy of Oslotre Arkitekter

p. 40-41 Close-up of facade of House in a Hill by ORGA architect. Courtesy of Bouwbedrijf Van Engen. Photography by Robert Koelewijn.

p. 45 Smooth dark wood finishing. Photography by Drazen Nesic, Unsplash.

p. 47 Hallway for employees at Mondzorg Middenmeer by ORGA architect. Photography by Ruben Visser.

p. 48-49 Hallway for visitors at Mondzorg Middenmeer by ORGA architect. Photography by Ruben Visser.

p. 51 Illustration of the neural network. Courtesy of Getty Images, Unsplash.

p. 52-53 Living room at House in a Hill by ORGA architect. Courtesy of Bouwbedrijf Van Engen. Photography by Robert Koelewijn.

p. 55 Stairwell at House in a Hill by ORGA architect. Courtesy of Bouwbedrijf Van Engen. Photography by Robert Koelewijn.

p. 56-57 Small foyer at House in a Hill by ORGA architect. Courtesy of Bouwbedrijf Van Engen. Photography by Robert Koelewijn.

p. 58 Illustration of MRI brainscan. Courtesy of Getty Images, Unsplash.

p. 59 Hallway view into living room at The Wooden House by ORGA architect. Photography by Rene de Wit.

p. 60-61 Photo's of the four test room setups from the research study at UBC. Photography David R. Fell.

p. 65 Guest bedroom at House in a Hill by ORGA architect. Courtesy of Bouwbedrijf Van Engen. Photography by Robert Koelewijn.

p. 66 MacMillan Bloedel Atrium inside the Forest Sciences Centre at the University of British Columbia. Photography by Amy Tran, Unsplash.

p. 68 Offices at the HasleTre building by Oslotre Arkitekter. Photography by Einar Aslaksen.

p. 69 Photo's of the two test rooms, taken from the open access research article by Dematté et al. (See endnote 28). Covered by https://creativecommons.org/licenses/by/4.0/.

p. 70-71 Breakroom at the HasleTre building by Oslotre Arkitekter. Photography by Einar Aslaksen.

p. 74 Close up of wooden handrail at the HasleTre building by Oslotre Arkitekter. Photography by Einar Aslaksen.

p. 76-77 PDX terminal redevelopment by ZGF architects and Terrapin Bright Green. Photography by Ema Peter

p. 78-79 Photo's of the two test rooms, taken from the open access research article by Ojala et al. (See endnote 50). Covered by https://creativecommons.org/licenses/by/4.0/.

p. 80-81 Renovated waiting room at the National Oncology Centre in Bratislava. Photography by Noro Knap.

p. 80 Photo of waiting room during the study, taken from the open access research article by Kotradyova et al. (See endnote 52). Covered by https://creativecommons.org/licenses/by/4.0/.

p. 82-83 The lobby at Credit Valley Hospital by Farrow Partners. Photography by Tom Arban.

p. 84-85 Stairwell at InnoRenew CoE. Courtesy of InnoRenew CoE. Photography by Miran Kambič.

p. 86-87 Municipal Yard Nieuwkoop by ORGA architect. Photography by Ruben Visser.

p. 90-91 Wildlife shelter Avolare by ORGA architect. Photography by Ruben Visser.

p. 94-95 Foyer at InnoRenew CoE. Courtesy of InnoRenew CoE. Photography by Miran Kambič.

p. 96-97 Primary school De Verwondering by ORGA architect. Photography by Ruben Visser.

p. 98-99 Primary school De Verwondering by ORGA architect. Photography by Ruben Visser.

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Wood & Wellbeing

Created by
ORGA architect

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Built by Nature

ORGA architect is a Dutch design studio that builds the case for biobased architecture one project at a time. Founded in 2007, the practice creates a wide variety of building types from timber and other natural materials, combining rigorous building physics knowledge with a biophilic design philosophy. Wood & Wellbeing is part of an ongoing effort to close the gap between scientific research and everyday building practice.

Built by Nature (BbN) is a not-for-profit organisation, with a mission to lead a global transformation of the built environment by accelerating the responsible use of timber and biobased materials. BbN connects demand-side construction industry leaders across Europe, fostering collaboration and knowledge sharing to drive systemic change. Its funding enables innovative cross-sector initiatives and amplifies the role of biobased materials in decarbonising construction.

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