A Literature Review on the Health Impacts of Wood and Mass Timber Buildings

APRIL 2025

COLLEGE OF BUILT ENVIRONMENTS
UNIVERSITY of WASHINGTON

Carbon Leadership Forum

About the Carbon Leadership Forum

The Carbon Leadership Forum is a nonprofit dedicated to accelerating the transformation of the building sector to radically reduce the greenhouse gas emissions attributed to materials (also known as embodied carbon) used in buildings and infrastructure. We research, educate, and foster cross-collaboration to bring the embodied carbon of buildings and infrastructure down to zero.

About the University of Washington (UW) Life Cycle Lab

The Life Cycle Lab at UW's College of Built Environments leads research to advance life cycle assessment (LCA) data, methods, and approaches to enable the optimization of materials, buildings, and infrastructure. Our work is structured to inform impactful policies and practices that support global decarbonization efforts. We envision a transformed, decarbonized building industry – better buildings for a better planet.

Authors

- Karisha Shahnaz Hariadi
- Stephanie Carlisle

CRediT authorship contribution: Writing — original draft, Formal analysis: K.S.H.; Writing — review and editing: S.C.; Methodology - K.S.H., S.C.; Investigation - K.S.H.; Conceptualization, Project Administration, Funding acquisition - S.C.

Competing interests statement: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

This research was conducted by researchers at the University of Washington. The initial draft of this work was completed in September 2024. It was supported by funding from the Laudes Foundation and the European Climate Fund as part of the Forest to Buildings project. We thank Mona Menadi and Peter Fraanje from Built By Nature (BbN) for their role in conceptualizing and providing feedback on this literature review and white paper. Kathrina Simonen from the Life Cycle Lab at the University of Washington also provided a review of the final document. The UW team would like to thank the Carbon Leadership Forum for their commitment to disseminating this work.

Cover Image by Phil Evenden..

Citation

Hariadi, K.S., & Carlisle, S. (2025). *A Literature Review on the Health Impacts of Wood and Mass Timber Buildings.* Carbon Leadership Forum, Bellevue, WA.

Copyright

Contents

1. Introduction

In response to the pressing need to reduce the environmental impact of the built environment, there has been growing interest in using bio-based building materials, including mass timber. Apart from potentially offering a lower carbon footprint compared to conventional structural materials, one emerging area of research is the potential positive and negative health impacts that mass timber may have on building occupants.

For decades, research has linked building materials and designs to the health and well-being of occupants (Nakanishi et al, 2024). This cross-disciplinary topic brings together researchers and experts from diverse disciplines such as material science, design, engineering, environmental psychology, psychiatry, environmental health, and public health. There is a robust and growing body of work on the linkages between human health and the built environment. While there is a larger body of work on the health impacts of wood used in the built environment more broadly, few studies have looked specifically at mass timber. Additionally, when mass timber buildings have been studied, the research is focused heavily on mass timber used in commercial, educational, and public buildings, with relatively fewer applications in residential construction. As a result, research on its health impacts in residential settings is still limited.

Linkages between construction material and occupant health and well-being are challenging to prove. While significant resources are devoted to assuring baseline levels of health and safety through tests such as flammability, structural soundness, and control over chemicals of significant concern, the softer impacts of materials on health and wellness – particularly mental health and well-being – remain understudied. When researchers look into these topics, the research often entails a small sample size, and it is therefore difficult to make clear assertions of causality.

Purpose

This paper is a literature review of the available scientific and industry literature on the documented health impacts of wood and mass timber in construction. The key health impacts discussed are:

- Improved indoor air quality
- Improved thermal comfort
- Enhanced cognitive performance
- Reduced stress levels
- Physiological relaxation

When research on mass timber specifically could not be found, findings on the health impacts of wood construction more broadly were collected and presented to bridge the knowledge gap. Due to the inherent similarities in the wood material properties and characteristics, many of the findings on the health and well-being impacts of wood in building spaces can provide valuable insights into mass timber construction. When a finding may not be applicable, this has been noted as well. This paper also explores trends in the types of buildings and occupants studied, identifies key researchers and organizations, and highlights gaps and opportunities for future research.

2. Literature Review Methodology

The following literature review was conducted using academic literature databases *Web of Science and ScienceDirect.* The key terms used were related to: (i) construction materials (e.g., mass timber, timber, wood); (ii) human health (e.g., health, wellbeing, physical, physiological, psychological, stress, cognitive); and (iii) building types (e.g., residential, school, office, healthcare). In parallel, an exploratory literature review was performed using AI-assisted research tools *Elicit* and *SciSpace*. Additional relevant studies were identified through backward citation chasing. Gray literature, including trade publications and white papers, was identified using Google Search with the same keywords. Source references are called out in footnotes and citations as "whitepapers" or "reports."

The review included journal articles published between 2000 and 2024. One highly cited paper from 1996 was included due to its relevance to the topic.

The studies selected were those presenting case studies and experimental studies that assessed the health impacts (e.g., physical, psychological, and physiological) of mass timber and wood structural and finishing materials on building occupants. Studies conducted in various indoor environments, such as residential, institutional, and public buildings were considered.

A total of 61 papers were reviewed, and 41 papers were included in this write-up. 14 papers focused on mass timber specifically, and the remaining focused on wood construction materials more broadly.

Table 1 provides a summary of the reviewed papers, their publication type and funding source, and their focus (building type, health attribute, and country).

Table 1. Overview of reviewed studies on the health impacts of mass timber and wood construction

Publication Type	Authors	Year	Title / Journal	Building type: Residential	Building type: Office	Building type: School	Building type: Healthcare	Building type: Others	Health Attribute: Stress	Health Attribute: Relaxation	Health Attribute: Cognitive	Health Attribute: Air Quality	Health Attribute: Thermal Comfort	Country	Funding (if disclosed)
Mass timber buildings/products															
Peer-reviewed	Nakanishi, E. Y., Poulin, P., Blanchet, P., Dubuis, M.-E., Drouin, M., Rhéaume, C., & Goupil-Sormany, I.	2024	A systematic review of the implications of construction materials on occupants' physical and psychological health. *Building and Environment*	●	●	●	●			●		●		Canada	Natural Sciences and Engineering Research Council of Canada (NSERC)
Peer-reviewed	Whyte, S., Kaburagi, R., Gan, V., Candido, C., Avazpour, B., Fatourehchi, D., Chan, H. F., Dong, Y., Dulleck, U., Finlay, S., Zhou, J., Hewson, N., Li, T., Maxwell, D., McNulty, C., & Sarnyai, Z.	2024	Exploring the Benefits of Mass Timber Construction in the Workplace: A Novel Primer for Research. *Buildings*		●			●	●	●	●	●	●	Australia	Building 4.0 CRC, Sumitomo Forestry Australia Pty Ltd. and Viridi Group Pty Ltd.
White paper	Stora Enso	2023	10 reasons why wooden buildings are good for you		●	●	●		●	●	●	●	●	Finland	
White paper	Salonvaara, M., Iffa, E., Desjarlais, A., & Atchley, J.	2022	Impact of Mass Wood Walls on Building Energy Use, Peak Demand, and Thermal Comfort. *Oak Ridge National Laboratory*	●									●	USA	US Department of Energy
Peer-reviewed	Li, J., Wu, J., Lam, F., Zhang, C., Kang, J., & Xu, H.	2021	Effect of the degree of wood use on the visual psychological response of wooden indoor spaces. *Wood Science and Technology*					●		●	●			China, Canada, UK	China Scholarship Council
White paper	Lowe, Graham	2020	Wood, Well-being and Performance: The Human and Organizational Benefits of Wood Buildings. (Naturally Wood)		●	●	●		●	●	●	●		Canada	Forestry Innovation Investment Ltd.
Peer-reviewed	Martindale, Katharine	2020	Industry driven innovation in healthy housing delivery: the case for Cross Laminated Timber. *Cities & Health*	●								●	●	UK	
White paper	Mithun Architects	2020	Mass Timber Schools: Building for Wellness. (Mithun Architects)			●			●	●	●	●		USA	Mithun's Research and Development Initiative, Bayley Construction and PCS Structural Engineers
Peer-reviewed	Yauk, M., Stenson, J., Donor, M., & Van Den Wymelenberg, K.	2020	Evaluating Volatile Organic Compound Emissions from Cross Laminated Timber Bonded with a Soy-Based Adhesive. *Buildings*									●		USA	USDA Agricultural Research Service
Peer-reviewed	Adekunle, Timothy O.	2019	Occupants' comfort and stress indices in a structural timber school building in the Northeast US in different seasons. *Building Research & Information*			●							●	USA	
Peer-reviewed	Stenson, J., Ishaq, S. L., Laguerre, A., Loia, A., MacCrone, G., Mugabo, I., Northcutt, D., Riggio, M., Barbosa, A., Gall, E. T., & Van Den Wymelenberg, K.	2019	Monitored Indoor Environmental Quality of a Mass Timber Office Building: A Case Study. *Buildings*		●							●		USA	USDA Agriculture Research Service, Biology and the Built Environment Center from the Alfred P. Sloan Foundation, Portland State University
Peer-reviewed	Tohmura, S., Miyamoto, K., & Inoue, A.	2005	Acetaldehyde emission from glued-laminated timber using phenol-resorcinol-formaldehyde resin adhesives with addition of ethanol. *Journal of Wood Science*	●								●		Japan	
Website	WO2	n/d	Nouvelle Qualite de Vie										●	France	
White paper	Bodemer, E., Kleinhenz, M., Erhard, L., Winter, S.	n/d	Gesundheitliche Interaktion von HOLZ – MENSCH – RAUM					●	●		●	●		Germany	Deutsche Bundesstiftung Umwelt
White paper	TRADA	n/d	The role of wood in healthy buildings. (*BRE, BM TRADA*)	●	●	●	●		●	●	●	●	●	UK	BRE Trust
Wooden structure in buildings															
White paper	City Zen Wood	2020	FCBA 2020 Report on the Influence of Wood on Comfort and Health						●	●	●			France	CODIFAB and France Bois Forêt
Peer-reviewed	Morita, E., Yanagisawa, M., Ishihara, A., Matsumoto, S., Suzuki, C., Ikeda, Y., Ishitsuka, M., Hori, D., Doki, S., Oi, Y., Sasahara, S., Matsuzaki, I., & Satoh, M	2020	Association of wood use in bedrooms with comfort and sleep among workers in Japan: a cross-sectional analysis of the SLeep Epidemiology Project at the University of Tsukuba (SLEPT) study. *Journal of Wood Science*	●						●				Japan	JSPS KAKENHI from the Ministry of Education, Culture, Sports, Science, and Technology, Japan
White paper	ThinkWood	2019	Wood and Indoor Environment Creating Beneficial Spaces for Living, Working, Well-Being	●	●	●	●	●	●	●	●	●		USA	

Publication Type	Authors	Year	Title / Journal	Building type: Residential	Office	School	Healthcare	Others	Health Attribute: Stress	Relaxation	Cognitive	Air Quality	Thermal Comfort	Country	Funding (if disclosed)
Peer-reviewed	Nore, K., Nyrud, A. Q., Kraniotis, D., Skulberg, K. R., Englund, F., & Aurlien, T.	2017	Moisture buffering, energy potential, and volatile organic compound emissions of wood exposed to indoor environments. *HVAC&R Research*	●								●	●	Norway, Sweden	Norwegian Research Council and the supporting industries
White paper	Wood2New	2017	Competitive wood-based interior materials and systems for modern wood construction	●	●	●	●		●			●	●	Finland	WoodWisdom-Net Research Programme
Peer-reviewed	Zhang, X., Lian, Z., & Wu, Y.	2017	Human physiological responses to wooden indoor environment. *Physiology & Behavior*		●				●	●				China	National Natural Science Foundation of China (NSFC)
White paper	Augustin, S., & Fell, D.	2015	Wood as a Restorative Material in Healthcare Environments. (FPInnovations)				●		●	●	●	●		Canada	Forestry Innovation Investment Ltd.
Peer-reviewed	Niedermayer, S., Fürhapper, C., Nagl, S., Polleres, S., & Schober, K. P.	2013	VOC sorption and diffusion behavior of building materials. *European Journal of Wood and Wood Products*									●		Austria	
Peer-reviewed	Rice, J., Kozak, R. A., Meitner, M. J., & Cohen, D. H.	2006	Appearance wood products and psychological well-being. *Wood and Fiber Science*	●					●	●				Canada	
Peer-reviewed	Tsunetsugu, Y., Miyazaki, Y., & Sato, H.	2002	The Visual Effects of Wooden Interiors in Actual-size Living Rooms on the Autonomic Nervous Activities. *Journal of Physiological Anthropology*	●						●				Japan	
Peer-reviewed	Hodgson, A. T., Rudd, A. F., Beal, D., & Chandra, S.	2000	Volatile Organic Compound Concentrations and Emission Rates in New Manufactured and Site-Built Houses. *Indoor Air*	●								●		USA	US Department of Energy
Website	Naturally:Wood	n/d	Health + wellness		●	●	●		●		●	●		Canada	Forestry Innovation Investment Ltd.
Website	SKANSKA	n/d	Beyond sustainability: four remarkable benefits of mass timber		●	●	●		●	●	●		●	USA	
Wooden finishes and furnishings in buildings															
Peer-reviewed	Mamić, D., & Domljan, D	2023	Positive Aspects of Using Solid Wood in Interiors on Human Wellbeing: A Review	●	●	●	●		●	●	●	●		Croatia	European Regional Development Fund in Croatia
Peer-reviewed	Häyrinen, L., Toppinen, A., & Toivonen, R	2020	Finnish young adults' perceptions of the health, well-being and sustainability of wooden interior materials. *Scandinavian Journal of Forest Research*	●					●			●		Finland	Puumiesten Ammattikasvatussaatio
Peer-reviewed	Lipovac, D., & Burnard, M. D.	2020	Effects of visual exposure to wood on human affective states, physiological arousal and cognitive performance: A systematic review of randomized trials. *Indoor and Built Environment*	●	●	●			●	●	●			Slovenia	InnoRenew CoE project, European Commission, Investment funding of the Republic of Slovenia and the European Union of the European Regional Development Fund
Peer-reviewed	Shen, J., Zhang, X., & Lian, Z.	2020	Impact of Wooden Versus Nonwooden Interior Designs on Office Workers' Cognitive Performance. *Perceptual and Motor Skills*		●						●			China	National Key R&D Program of China
Peer-reviewed	Sun, M., Nakashima, T., Yoshimura, Y., Honden, A., Nakagawa, T., Saijo, H., Watanabe, Y., Ajimi, T., Yasunari, S., Yamada, Y., Nagano, J., Okamoto, T., Ishikawa, H., Ohnuki, K., Fujimoto, N., & Shimizu, K.	2020	Effects and interaction of different interior material treatment and personal preference on psychological and physiological responses in living environment. *Journal of Wood Science*	●						●				Japan	Natural Science Foundation of Zhejiang Province
Peer-reviewed	Kotradyova, V., Vavrinsky, E., Kalinakova, B., Petro, D., Jansakova, K., Boles, M., & Svobodova, H	2019	Wood and Its Impact on Humans and Environment Quality in Health Care Facilities. *International Journal of Environmental Research and Public Health*				●		●			●		Slovakia	Slovak Research and Development Agency, Ministry of Education, Science, Research and Sport of the Slovak Republic
Peer-reviewed	Demattè, M. L., Zucco, G. M., Roncato, S., Gatto, P., Paulon, E., Cavalli, R., & Zanetti, M.	2018	New insights into the psychological dimension of wood–human interaction. *European Journal of Wood and Wood Products*					●	●	●				Italy	University of Padova: Progetto di ricerca di Ateneo
White paper	Knox, A., & Parry-Husbands, H	2018	Workplaces: Wellness + Wood = Productivity. (Pollinate)		●				●		●			Australia	Forest & Wood Products Australia
Peer-reviewed	Burnard, M. D., & Kutnar, A.	2015	Wood and human stress in the built indoor environment: a review. *Wood Science and Technology*	●	●	●	●		●					Slovenia	Italy-Slovenia Cross-border Cooperation Programme within the project EnergyViLLab, Slovenian Research Agency

Publication Type	Authors	Year	Title / Journal	Building type: Residential	Office	School	Healthcare	Others	Health Attribute: Stress	Relaxation	Cognitive	Air Quality	Thermal Comfort	Country	Funding (if disclosed)
Peer-reviewed	Matsubara, E., & Kawai, S.	2014	VOCs emitted from Japanese cedar (Cryptomeria japonica) interior walls induce physiological relaxation. *Building and Environment*					●		●				Japan	
Peer-reviewed	Yeh, M., Tsai, Y., Lin, Y., Tseng, W., & Lin, Y	2014	Investigation of color images and visual responses of electroencephalograms to wooden flooring. *Taiwan Journal of Forest Science*	●						●				Taiwan	
Peer-reviewed	Anme, T., Watanabe, T. M., Tokutake, K. M., Tomisaki, E. M., Mochizuki, H. M., Tanaka, E. M., & Asada, S.	2012	Behavior Changes in Older Persons Caused by Using Wood Products in Assisted Living. *Public Health Research*				●				●			Japan	Grants-in-Aid for Scientific Research (KAKENHI)
Peer-reviewed	Alapieti, T., Mikkola, R., Pasanen, P., & Salonen, H.	2010	The influence of wooden interior materials on indoor environment: a review. *European Journal of Wood and Wood Products*	●	●	●	●		●	●		●	●	Finland	Finnish Funding Agency for Technology & Innovation (TEKES), Aalto University
Dissertation	Fell, D. R.	2010	Wood in the human environment: restorative properties of wood in the built indoor environment. (*University of British Columbia*)		●				●					Canada	FPInnovations, EDU - UBC
Peer-reviewed	Nyrud, A., & Bringslimark, T.	2010	Is interior wood use psychologically beneficial? A review of psychological responses toward wood. *Wood and Fiber Science*	●	●		●		●	●	●			Norway	
Peer-reviewed	Tsunetsugu, Y., Miyazaki, Y. & Sato, H.	2007	Physiological effects in humans induced by the visual stimulation of room interiors with different wood quantities. *Journal of Wood Science*	●						●				Japan	Ministry of Education, Culture, Sports, Science and Technology
Paper	Lenz, K., Krus, M., & Holm, A.	2005	Feuchtepufferverhalten von Innenraum-Materialien in Holz.					●				●		Germany	
Website	ThinkWood	n/d	Biophilic Architecture + Building Design		●	●	●		●	●	●			USA	
Other wood products derived stimuli															
Smell (Olfactory Stimuli)															
Peer-reviewed	Matsubara, E., Matsui, N., & Ohira, T.	2020	Evaluation of the psychophysiological effects of the Cupressaceae family wood odor. *Wood Science and Technology*							●				Japan	
Peer-reviewed	Adamová, T., Hradecký, J., & Pánek, M.	2020	Volatile Organic Compounds (VOCs) from Wood and Wood-Based Panels: Methods for Evaluation, Potential Health Risks, and Mitigation. *Polymers*									●		Czech Republic	
Peer-reviewed	Chen, C.-J., Kumar, K. J. S., Chen, Y.-T., Tsao, N.-W., Chien, S.-C., Chang, S.-T., Chu, F.-H., & Wang, S.-Y	2015	Effect of Hinoki and Meniki Essential Oils on Human Autonomic Nervous System Activity and Mood States. *Natural Product Communications*							●				Taiwan	Ministry of Science and Technology, Ministry of Education, Taiwan
Peer-reviewed	Guo, H., Murray, F., & Lee, SC.	2002	Emissions of total volatile organic compounds from pressed wood products in an environmental chamber. *Building and Environment*									●		Australia, Hong Kong	
Peer-reviewed	Jensen, LK., Larsen, A., Molhave, L., Hansen, MK., & Knudsen, B.	2001	Health evaluation of volatile organic compound (VOC) emissions from wood and wood-based materials. *Archives of Environmental Health: An International Journal*									●		Denmark	Danish Environmental Protection Agency
Touch (Tactile Stimuli)															
Peer-reviewed	Ikei, H., Song, C., & Miyazaki, Y.	2017	Physiological effects of touching coated wood. *International Journal of Environmental Research and Public Health*						●	●				Japan	Ministry of Education, Culture, Sports, Science and Technology, Japan (MEXT), Japan Society for the Promotion of Science, Grants-in-Aid for Scientific Research (KAKENHI)
Peer-reviewed	Ikei, H., Song, C., & Miyazaki, Y.	2017	Physiological effects of touching wood. *International Journal of Environmental Research and Public Health*						●	●				Japan	Ministry of Education, Culture, Sports, Science and Technology, Japan (MEXT), Japan Society for the Promotion of Science, Grants-in-Aid for Scientific Research (KAKENHI)

Publication Type	Authors	Year	Title / Journal	Building type: Residential	Office	School	Healthcare	Others	Health Attribute: Stress	Relaxation	Cognitive	Air Quality	Thermal Comfort	Country	Funding (if disclosed)
Peer-reviewed	Yi, X., Zhao, D., Ou, R., Ma, J., Chen, Y., & Wang, Q.	2017	A Comparative Study of the Performance of Wood-Plastic Composites and Typical Substrates as Heating Floor. *Bioresources*						●				●	China	Fundamental Research Funds for the Central Universities, National Natural Science Foundation of China (NSFC)
Peer-reviewed	Sakuragawa, S., Kaneko, T., & Miyazaki, Y	2008	Effects of contact with wood on blood pressure and subjective evaluation. *Journal of Wood Science*						●	●				Japan	
Peer-reviewed	Morikawa, T., Miyazaki, Y., & Kobayashi, S.	1998	Time-series variations of blood pressure due to contact with wood. *Journal of Wood Science*						●	●				Japan	
Sight (Visual Stimuli)															
Peer-reviewed	Ikei, H., Nakamura, M., & Miyazaki, Y.	2020	Physiological Effects of Visual Stimulation Using Knotty and Clear Wood Images among Young Women. *Sustainability*						●	●				Japan	Tokyo log wholesalers' association
Peer-reviewed	Nakamura, M.; Ikei, H.; Miyazaki, Y	2019	Physiological effects of visual stimulation with full-scale wall images composed of vertically and horizontally arranged wooden elements. *Journal of Wood Science*						●	●				Japan	Tokyo log wholesalers' association
Supporting information															
Peer-reviewed	Szabados, M., Magyar, D., Tischner, Z., & Szigeti, T.	2023	Indoor air quality in Hungarian Passive Houses. *Atmospheric Environment*	●								●	●	Hungary	
Peer-reviewed	Maung, T. Z., Bishop, J. E., Holt, E., Turner, A. M., & Pfrang, C.	2022	Indoor Air Pollution and the Health of Vulnerable Groups: A Systematic Review Focused on Particulate Matter (PM), Volatile Organic Compounds (VOCs) and Their Effects on Children and People with Pre-Existing Lung Disease. *International Journal of Environmental Research and Public Health*	●			●	●				●		UK	Natural Environment Research Council, NERC
Peer-reviewed	Dreyer, B. C., Coulombe, S., Whitney, S., Riemer, M., & Labbé, D.	2018	Beyond Exposure to Outdoor Nature: Exploration of the Benefits of a Green Building's Indoor Environment on Wellbeing. *Frontiers in Psychology*		●									Canada	
White paper	Browning, W.D., Ryan, C.O., Clancy, J.O.	2014	14 Patterns of Biophilic Design. New York: Terrapin Bright Green llc						●	●	●			USA	
Peer-reviewed	Andersson, K., Bakke, J. V., Bjorseth, O., Bornehag, C.-G., Clausen, G., Hongslo, J. K., Kjellman, M., Kjaergaard, S., Levy, F., Molhave, L., Skerfving, S., & Sundell, J	1997	TVOC and Health in Non-industrial Indoor Environments. *Indoor Air*					●				●		Sweden, Norway, Denmark	

3. Overview of Existing Studies

Research on the health impacts of mass timber buildings has broadened over time. Earlier studies on this topic primarily focused on air quality and other easily measurable building performance attributes associated with a novel material and application (Tohmura et al, 2005). However, in the past five years, research has explored additional aspects of mass timber construction that explore a wider range of physical and psychological health impacts, including cognitive performance, stress, and thermal comfort (Lowe, 2020; Li et al, 2021). These studies, often funded by government initiatives, have been conducted in regions with strong mass timber efforts, including Austria, UK, USA, Canada, Finland, Japan, and Australia.

Mass timber studies have covered a variety of building types, including housing. However, research on the health impacts of mass timber in residential developments is still very limited since its use in this sector is less common compared to commercial, educational, and public buildings. Despite this limitation, a 2020 study in the UK, which involved interviews with architects, found that the second most frequently mentioned benefit of using cross-laminated timber (CLT) in homes was its perceived positive impact on health (Martindale, 2020). The benefits mentioned were related to reduced humidity levels, the “like-ability” of timber, acoustic benefits, and well-being.

Beyond the focus on mass timber, there is extensive literature on the health benefits and impacts of using wood as an interior building material (Alapieti et al, 2020; Burnard & Kutnar, 2015; Mamić & Domljan, 2023). Due to the limited number of mass timber studies, researchers often refer to the broader wood-product literature. The main health impacts discussed include reduced stress levels and physiological relaxation. These studies have been carried out in regions with abundant wood resources and widespread usage, such as Canada, Japan, Australia, China, Scandinavia, Austria, and the United States. These studies primarily focus on the health impacts and benefits of exposed wood in indoor environments, with attention to its uses in office, healthcare, and educational settings.

A growing number of trade publications have also provided comprehensive summaries on the health impacts associated with wooden buildings, with few references to mass timber structures (Stora Enso, n.d.; Curtis et al, 2022; WO2, n.d.; ThinkWood, 2019). These studies often cover both physical and mental health impacts, as well as the effects of active and passive interactions with wood or timber.

Table 2 provides a summary of the health impacts of mass timber and wood construction that have been explored in the academic and trade literature.

Table 2. Summary of findings on the health impacts of mass timber and wood construction by studies on wood products and mass timber

Measure	Summary of studies by product type	
	General wood products	**Mass timber**
Indoor air quality	Wood-based panels have the potential to reduce VOCs in indoor air (Niedermayer et al., 2013; Kotradyova et al., 2019)	Mixed conclusions due to the complexity of indoor air quality attributes, variety of wood species and adhesives/additives used in manufacturing, as well as varying methodological approaches. For example: • An eight-month-old CLT panel made with melamine formaldehyde exceeded the formaldehyde standard of 9.0 µg/m^3, with an estimated indoor air concentration of 54.4 µg/m^3 (Yauk et al., 2020). • A one-year-old CLT and glulam office building have formaldehyde levels below the WHO guidelines of 81 ppb (Stenson et al., 2019).
Thermal comfort	Wooden cladding and timber planks can help buffer moisture fluctuations (Lenz et al., 2005; Wood2New, 2017)	Mass timber walls can enhance thermal comfort and contribute to energy savings (Salonvaara et al., 2022)
Cognitive performance	Workers in rooms with wooden structures and/or surfaces have higher levels of concentration, improved mood, and personal productivity (Knox & Parry-Husbands, 2018; Shen et al., 2020)	Better attention, reaction times, and well-being ratings of occupants in spaces made of CLT and clay compared to those in steel spaces (Zingerle et al., 2015)
Stress levels	Rooms with wooden finishes and furnishings provide stress-reducing effects (Fell, 2010; Zhang et al., 2017; Kotradyova et al., 2019)	Trade workers working in a mass timber construction site have lower cortisol (stress hormone) compared to a concrete site (Whyte et al., 2024).
Physiological effects	Seeing, smelling, and/or touching wood-based materials promotes a relaxed state (Tsunetsugu et al., 2002; Sakuragawa et al., 2008; Matsubara et al., 2014)	*No studies found on this topic*

3.1 Improved Indoor Air Quality

Most earlier research on the health impacts of wood-based materials used in the built environment have focused on factors related to healthy indoor air quality, with an emphasis on volatile organic compounds (VOCs) (Guo et al, 2002; Jensen et al, 2001).

VOCs are a large group of chemicals that can vaporize easily into the air at room temperature. Concentrations of VOCs are consistently higher indoors, with concentrations up to ten times higher than outdoor air, and have been linked to a range of adverse health outcomes ranging from asthma to cancer (Maung et al, 2022). Many VOCs associated with poor indoor air quality are linked to a wide range of chemicals, adhesives, and plastics. However, VOCs also occur naturally and are produced by animals and plants, including wood. Different VOCs can have various effects on human health, ranging from no impact to acute health issues and discomfort

(Andersson et al, 1997). While there are guidelines for safe exposure levels to individual VOCs, the effects of exposure to multiple VOCs, especially over a long time, are not as well understood (TRADA, n.d.).

For wood, the composition of VOCs emitted varies depending on the wood species and the organic compounds that are present within a wood cell wall, known as extractive composition (Adamová et al, 2020). Additionally, the use of adhesives and additives, such as phenol-formaldehyde, in mass timber or engineered wood products can further contribute to off-gassing and VOCs. Many studies have assessed the concentration of varying VOCs in engineered wood buildings, including mass timber (Stenson et al, 2019; Tohmura et al, 2005). Other studies have also looked at the health implications to the building occupants (Nore et al, 2017). These studies reported mixed findings: some report high VOC levels, while others find them low; some associate the emissions with symptoms like dizziness or nausea, while others, especially in Japan, note a pleasant experience due to natural VOCs. These varying conclusions can be attributed not only to differences in wood species and the types of VOCs emitted but also to the complexity of indoor air quality, which is influenced by factors like humidity, temperature, and other pollutants in the space, as well as air movement and ventilation rates. Managing indoor air quality and VOC levels can be particularly challenging in high-performance buildings or any construction with high airtightness and well-insulated envelope (Szabados et al, 2023). Different methodological approaches among studies, such as timing and duration of study, as well as sampling techniques, can also influence the results.

In addition to VOCs originating from wood, an emerging area of research looks at the interaction between wood-based building materials and VOCs from other sources. For instance, a study based in Austria examined 25 common building materials used in timber construction, including wood-based panels, and assessed their ability to absorb, release, and let the VOCs pass through them (Niedermayer et al, 2013). The tests showed that some of the materials have a high potential to reduce VOCs in indoor air. Most of the tested building materials, including solid wood, absorbed about 50% or higher of the VOCs they were exposed to.

An experimental study which took place at the National Oncology Institute in Bratislava, Slovakia, also evaluated changes in VOC concentration before and after the renovation of the wooden waiting room (Kotradyova et al, 2019). After renovating the foyer and adding wooden furnishings, there was a noticeable decrease in VOCs from cleaning agents and solvents three weeks post-renovation. This was suggested to be due to the wood absorbing and then slowly releasing these VOCs. However, VOC levels in renovated and non-renovated areas were similar after three months. The study acknowledges that more tests in areas with less ventilation are needed to confirm wood's absorptive effects. In addition, the renovation and wood installation changed the VOC profile, introducing new wood-specific VOCs.

3.2 Improved Thermal Comfort

Maintaining ideal temperature and moisture levels in a building is very important for the health and comfort of the occupants. Research suggests that these factors can be influenced by the building materials. Mass timber, in particular, is gaining recognition for its effective temperature and moisture-buffering capabilities due to its high thermal mass.

A recent project for the US Department of Energy evaluated how mass timber can enhance thermal comfort for occupants and contribute to energy savings (Salonvaara, 2022). Using a whole-building simulation tool validated by lab testing, the analysis showed that mass timber walls generally enhance thermal comfort by reducing the number of hours in which the building interior fell outside of a normal comfort zone. For instance, solid mass timber walls cut hours in which mechanical heating, cooling, or ventilation would be required by 31% in Houston, TX, and 46% in Los Angeles, CA, but increased them by 35% in Golden, CO, due to higher thermal transmittance, or U-value. However, when exterior insulation was added to mass timber walls, discomfort hours decreased across all locations, demonstrating the material's potential for enhancing indoor comfort and energy efficiency.

A project based in Finland called Wood2New examined how wood interacts with moisture and confirmed the beneficial properties of wood to buffer moisture fluctuations (Wood2New, 2017). When humidity rises, wood absorbs moisture from the air; when it falls, wood releases the stored moisture back. This process releases heat during absorption, which can warm the wood's surface and requires heat during release. These characteristics, along with wood's other thermal properties, contribute to the concept of 'hygrothermal mass,' which can also contribute to improving building energy efficiency.

A 2016 case study at the Kiwi Fjeldset supermarket in Norway retrofitted wood into the ceiling to buffer moisture fluctuations. This adjustment led to reduced use of mechanical ventilation with heat recovery units. Another study compared two identical rooms: one with gypsum plaster and the other with wooden surfaces. It found that untreated flat wooden cladding reduced air humidity fluctuations by up to 70%, while round timber planks reduced it by 44%-63% compared to gypsum plaster (Lenz et al, 2005).

3.3 Improved Cognitive Performance

One of the well-researched areas on the impact of interior design elements (including both interior finishes and furnishings) on human health is their effect on the occupants' cognitive performance. Recently, studies have expanded to focus on the effects of exposed structural elements, such as mass timber. The few studies found on cognitive performance were conducted in office and educational buildings (Knox et al, 2018; Lowe, 2020). Cognitive function includes thinking, learning, reasoning, remembering, problem-solving, and decision-making. However, the studies identified were published only in trade publications and could not be found in peer-reviewed journals. The preliminary findings from these studies indicate that exposed wood and other natural materials used in interiors may contribute to an overall improvement in cognitive performance.

In 2015, a study at the University of Innsbruck, Austria, tested people in four different interior spaces made from different construction materials: cross-laminated timber (CLT), plaster, steel, and steel with plaster elements. People in the spaces made of CLT and plaster/gypsum showed better attention and reaction times. They also rated their well-being higher in spaces with natural elements compared to the steel space (Zingerle et al, 2015).

A study published by *Forest & Wood Products Australia* investigated the relationship between exposure to wooden finishes in the workplace and workers' reported well-being (Knox & Parry-Husbands, 2018). In this study, a survey of 1,000 indoor Australian workers was conducted and found that exposed wood surfaces were correlated with higher levels of concentration, improved mood, and personal productivity. Those working in wooden environments have higher levels of satisfaction and well-being and take less leave. Additional biophilic design elements, such as plants and natural lights, further boost workplace satisfaction.

A similar study, with a very small sample size, conducted in China with 20 adults found the participants reported better attention and productivity in rooms with wooden structures and finishes than in non-wooden ones. They also preferred wooden rooms over concrete rooms for working. Additionally, participants performed better on neurobehavioral tests in wooden environments, with faster completion times and more correct answers on various tests (Shen et al, 2020).

3.4 Reduced Stress Levels

One of the most well-documented benefits of bio-based materials in interior environments is that they help reduce stress and improve overall well-being. Extensive research in the field of environmental psychology has demonstrated that the presence of natural elements in indoor spaces, including those with exposed wooden elements, can have a restorative effect on the human mind and body. These biophilic benefits of wood have been observed in a variety of settings, from healthcare facilities to office spaces, and educational institutions (Augustin & Fell, 2015; Zhang et al, 2017; Fell, 2010). It is to be noted that covered or concealed structural wood may not provide the same benefits.

These studies often focus on how exposure to wood in indoor settings can affect the occupants' autonomic nervous system, among others. Fell (2010) defined the autonomic nervous system as regulating involuntary bodily functions such as the heart, smooth muscle, and glands. It consists of sympathetic and parasympathetic branches that work in tandem to adapt to environments and stress. The sympathetic nervous system prepares the body to react to stress, often characterized as the "fight or flight" response. The parasympathetic nervous system relaxes the body and allows for maintenance and recovery functions, which are characterized as the "rest and digest" response.

These studies came to the same conclusion: subjects in a room with wood finishes and furnishings had a lower sympathetic system activation than those in a room without wood. Although there may be no changes in the parasympathetic system, these studies suggest that wood provides stress-reducing effects similar to the effect of exposure to nature.

Another study used the wooden waiting room at the National Oncology Institute in Bratislava, Slovakia, to assess the stress-reducing effects of wood (Kotradyova et al, 2019). The participants ' brain activity, facial expression, heart rate, respiration, blood pressure, and cortisol levels were measured. Results of the brain activity measurement concluded that the effect of exposure to wood finishes and furnishings during the first few minutes was relaxing. During longer stays in the wood environment, the brains became more active, less afraid, and nervous, and their memory and ability to think increased. In addition, sympathetic activity decreased while parasympathetic activity was enhanced, indicating that the participants felt more relaxed. Cortisol level also declined by 7.5%, suggesting that wood has an anti-stress impact.

A recent Australian study investigated the impacts and benefits of mass timber construction on construction workers. Over three months, workers operated on a mass timber building before transitioning to a concrete building. Despite the study's small sample size, hair cortisol testing showed that workers had lower cortisol (stress hormone) levels while working on the mass timber building site compared to when they were on the concrete building site (Whyte et al, 2024).

3.5 Physiological Effects

A growing number of studies, primarily from Japan and Taiwan, have explored the physiological effects of wood-derived stimuli. Different types of stimulation, such as sight, smell, and touch, have been used in these studies. These observed effects are relevant to any type of exposed wood material. Thus, covered or concealed structural wood may not provide the same benefits. One of the earlier studies on this topic used visual stimulation to reveal that the use of wood for various purposes in living rooms (i.e., floor, wall, beams, and columns) has different effects on the physiological parameters of the participants, such as blood pressure and pulse rate (Tsunetsugu, 2002; Tsunetsugu, 2007). Later studies, such as those done by Yeh et al. (2014), found that participants looking at wooden flooring instead of ceramic tiles showed lower alpha wave activity, which was linked to relaxation and comfort.

Similarly, studies that looked at the physiological effects of wood scent reported that the volatile organic compounds (VOCs) from Japanese cedar interior walls suppressed the activation of the sympathetic nervous activity, thus promoting a relaxed state (Matsubara & Kawai, 2014). A study by Chen et al. (2015) reported that the essential oil from Taiwan red cypress, i.e., Meniki, suppressed the activation of the sympathetic nervous system, reduced blood systolic pressure, and increased blood diastolic pressure, all of which are indicative of a more relaxed physiological state. Studies focusing on wood contact have also demonstrated physiological relaxation effects, as evidenced by the work of Sakuragawa et al. (2008) and Ikei et al. (2017). Notably, these effects from wood-derived stimuli may be culturally dependent and have not been widely studied.

4. Gaps and Future Opportunities

The growing interest in mass timber construction as a sustainable building material has led to an increased focus on understanding its advantages, including potential health benefits to building occupants. Despite this growing interest, research on this topic remains limited in scope:

- Categories of health impacts investigated for mass timber buildings tend to be narrow, with a predominant focus on indoor air quality and thermal comfort, and little to no specific work on mental health, well-being, and cognitive effects.
- Existing studies mostly exclude residential settings, since the use of mass timber is more common in commercial, educational, and public buildings.
- The discussion about the effects on the occupants' physiological and psychological stress still largely relies on broader wood products or natural building material literature.

The literature that has been published has several key limitations, as discussed by Lipovac and Burnard (2021) and Nakanishi et al. (2024):

- For studies that look at the physiological effects, the limitations often observed were small sample sizes (less than 20 subjects, some of which are gender-specific) and short assessment periods (less than 30 minutes, some are only 90 seconds).
- Lipovac and Burnard (2020) also highlighted that few studies that measure stress levels did not incorporate a stress-inducing activity, which may lead to inconclusive results.
- Most of these studies have been conducted in experimental settings rather than in real-world building environments.

The discussion on the effects on occupant health remains a subject of debate due to the complexities involved in establishing a clear causal relationship. Many studies do not account for a broader range of factors that can influence occupants' health. These factors are elements typically included in healthy building frameworks, such as lighting, acoustics, overall comfort, and most critically, the presence of toxic materials or chemicals. Particularly for housing, factors like personal habits, furnishing preferences, and individual priorities, and the condition and quality of mechanical equipment and building services play a significant role in shaping the health outcomes for occupants. It is possible that since mass timber is often used in relatively niche and high-quality projects, some of the observed health benefits may also be attributed to a high project budget and high-quality design and construction.

As mass timber buildings become more prevalent and form a more diverse section of the built environment, there are opportunities to explore a range of targeted questions about this fascinating connection between construction materials, environmental impacts, and impacts on occupant health and well-being.

References

Peer-Review Literature

Adamová, T., Hradecký, J., & Pánek, M. (2020). Volatile Organic Compounds (VOCs) from Wood and Wood-Based Panels: Methods for Evaluation, Potential Health Risks, and Mitigation. *Polymers. 12(10):2289.* https://doi.org/10.3390/polym12102289

Alapieti, T., Mikkola, R., Pasanen, P., & Salonen, H. (2020). The influence of wooden interior materials on indoor environment: a review. *European Journal of Wood and Wood Products*, 78(4), 617–634. https://doi.org/10.1007/s00107-020-01532-x

Andersson, K., Bakke, J. V., Bjorseth, O., Bornehag, C.-G., Clausen, G., Hongslo, J. K., Kjellman, M., Kjaergaard, S., Levy, F., Molhave, L., Skerfving, S., & Sundell, J. (1997). TVOC and Health in Non-industrial Indoor Environments. Report from a Nordic Scientific Consensus Meeting at Langholmen in Stockholm, 1996. *Indoor Air,* 7(2), 78–91. https://doi.org/10.1111/j.1600-0668.1997.t01-2-00002.x

Burnard, M. D., & Kutnar, A. (2015). Wood and human stress in the built indoor environment: a review. *Wood Science and Technology*, 49(5), 969-986. https://doi.org/10.1007/s00226-015-0747-3

Chen, C.-J., Kumar, K. J. S., Chen, Y.-T., Tsao, N.-W., Chien, S.-C., Chang, S.-T., Chu, F.-H., & Wang, S.-Y. (2015). Effect of Hinoki and Meniki Essential Oils on Human Autonomic Nervous System Activity and Mood States. *Natural Product Communications*, 10(7), 1305–1308. https://doi.org/10.1177/1934578X1501000742

Fell, D. R. (2010). Wood in the human environment : restorative properties of wood in the built indoor environment (T). Thesis: University of British Columbia. Retrieved June 18, 2024 from https://open.library.ubc.ca/collections/ubctheses/24/items/1.0071305

Guo, H., Murray, F., & Lee, SC. (2002). Emissions of total volatile organic compounds from pressed wood products in an environmental chamber. *Building and Environment*, 37(11): 1117-1126. https://doi.org/10.1016/S0360-1323(01)00107-X

Ikei, H., Song, C., & Miyazaki, Y. (2017). Physiological effects of touching coated wood. *International Journal of Environmental Research and Public Health*, 14 (7): 773. https://doi.org/10.3390/ijerph14070773

Jensen, LK., Larsen, A., Molhave, L., Hansen, MK., & Knudsen, B. (2001). Health evaluation of volatile organic compound (VOC) emissions from wood and wood-based materials. *Archives of Environmental Health*, 56(5): 419-432. https://doi.org/10.1080/00039890109604477

Kotradyova, V., Vavrinsky, E., Kalinakova, B., Petro, D., Jansakova, K., Boles, M., & Svobodova, H. (2019). Wood and Its Impact on Humans and Environment Quality in Health Care Facilities. *International Journal of Environmental Research and Public Health*, 16(18), 3496. https://doi.org/10.3390/ijerph16183496

Lenz, K., Krus, M., Holm, A. (2005). Feuchtepufferverhalten von Innenraum-Materialien in Holz. (Research Methodology Report, Fraunhofer Institute for Building Physics). Retrieved June 24, 2024 from https://wufi.de/literatur/Lenz,%20Krus%20et%20al%202005%20-%20Feuchtepufferverhalten%20von%20Innenraum-Materialien%20in%20Holz.pdf

Li, J., Wu, J., Lam, F., Zhang, C., Kang, J., & Xu, H. (2021). Effect of the degree of wood use on the visual psychological response of wooden indoor spaces. *Wood Science and Technology*, 55(5), 1485–1508. https://doi.org/10.1007/s00226-021-01320-7

Lipovac, D., & Burnard, M. D. (2021). Effects of visual exposure to wood on human affective states, physiological arousal and cognitive performance: A systematic review of randomized trials. *Indoor + Built Environment,* 30(8), 1021–1041. https://doi.org/10.1177/1420326X20927437

Mamić, D., & Domljan, D. (2023). Positive Aspects of Using Solid Wood in Interiors on Human Wellbeing: A Review. *Drvna industrija* 74 (3) p379-391.https://doi.org/10.5552/drvind.2023.0130

Martindale, K. (2020). Industry driven innovation in healthy housing delivery: the case for Cross Laminated Timber. *Cities & Health*, 4(2), 206–212. https://doi.org/10.1080/23748834.2020.1735157

Matsubara, E., & Kawai, S. (2014). VOCs emitted from Japanese cedar (Cryptomeria japonica) interior walls induce physiological relaxation. *Building and Environment*, 72, 125–130. https://doi.org/10.1016/j.buildenv.2013.10.023

Maung, T. Z., Bishop, J. E., Holt, E., Turner, A. M., & Pfrang, C. (2022). Indoor Air Pollution and the Health of Vulnerable Groups: A Systematic Review Focused on Particulate Matter (PM), Volatile Organic Compounds (VOCs) and Their Effects on Children and People with Pre-Existing Lung Disease. *International Journal of Environmental Research and Public Health*, 19(14), 8752. https://doi.org/10.3390/ijerph19148752

Nakanishi, E. Y., Poulin, P., Blanchet, P., Dubuis, M.-E., Drouin, M., Rhéaume, C., & Goupil-Sormany, I. (2024). A systematic review of the implications of construction materials on occupants' physical and psychological health. *Building and Environment*, 257, 111527-. https://doi.org/10.1016/j.buildenv.2024.111527

Niedermayer, S., Fürhapper, C., Nagl, S., Polleres, S., & Schober, K. P. (2013). VOC sorption and diffusion behavior of building materials. *European Journal of Wood and Wood Products*, 71(5), 563–571. https://doi.org/10.1007/s00107-013-0713-4

Nore, K., Nyrud, A. Q., Kraniotis, D., Skulberg, K. R., Englund, F., & Aurlien, T. (2017). Moisture buffering, energy potential, and volatile organic compound emissions of wood exposed to indoor environments. *HVAC&R Research*, 23(3), 512–521. https://doi.org/10.1080/23744731.2017.1288503

Sakuragawa, S., Kaneko, T., & Miyazaki, Y. (2008). Effects of contact with wood on blood pressure and subjective evaluation. *Journal of Wood Science*, 54 (2): 107-113. https://doi.org/10.1007/s10086-007-0915-7

Salonvaara, M., Iffa, E., Desjarlais, A., & Atchley, J. (2022). Impact of Mass Wood Walls on Building Energy Use, Peak Demand, and Thermal Comfort. (Report, Oak Ridge National Laboratory. ORNL/TM-2022/2375). Retrieved June 21, 2024 from https://info.ornl.gov/sites/publications/Files/Pub174562.pdf

Shen, J., Zhang, X., & Lian, Z. (2020). Impact of Wooden Versus Non Wooden Interior Designs on Office Workers' Cognitive Performance. *Perceptual and Motor Skills*, 127(1), 36–51. https://doi.org/10.1177/0031512519876395

Stenson, J., Ishaq, S. L., Laguerre, A., Loia, A., MacCrone, G., Mugabo, I., Northcutt, D., Riggio, M., Barbosa, A., Gall, E. T., & Van Den Wymelenberg, K. (2019). Monitored Indoor Environmental Quality of a Mass Timber Office Building: A Case Study. *Buildings*, 9(6), 142. https://doi.org/10.3390/buildings9060142

Szabados, M., Magyar, D., Tischner, Z., & Szigeti, T. (2023). Indoor air quality in Hungarian Passive Houses. *Atmospheric Environment*, 307, 119857. https://doi.org/10.1016/j.atmosenv.2023.119857

Tohmura, S., Miyamoto, K., & Inoue, A. (2005). Acetaldehyde emission from glued-laminated timber using phenol-resorcinol-formaldehyde resin adhesives with addition of ethanol. *Journal of Wood Science*, 51(4), 421–423. https://doi.org/10.1007/s10086-005-0726-7

Tsunetsugu, Y., Miyazaki, Y., & Sato, H. (2002). The Visual Effects of Wooden Interiors in Actual-size Living Rooms on the Autonomic Nervous Activities. *Journal of Physiological Anthropology*, 21(6), 297-. https://doi.org/10.2114/jpa.21.297

Tsunetsugu, Y., Miyazaki, Y., & Sato, H. (2007). Physiological effects in humans induced by the visual stimulation of room interiors with different wood quantities. *Journal of Wood Science*, 53, 11-16. https://doi.org/10.1007/s10086-006-0812-5

Whyte, S., Kaburagi, R., Gan, V., Candido, C., Avazpour, B., Fatourehchi, D., Chan, H. F., Dong, Y., Dulleck, U., Finlay, S., Zhou, J., Hewson, N., Li, T., Maxwell, D., McNulty, C., & Sarnyai, Z. (2024). Exploring the Benefits of Mass Timber Construction in the Workplace: A Novel Primer for Research. *Buildings*, 14(7), 2072-. https://doi.org/10.3390/buildings14072072

Yeh, M., Tsai, Y., Lin, Y., Tseng, W., & Lin, Y. (2014). Investigation of color images and visual responses of electroencephalograms to wooden flooring. *Taiwan Journal of Forest Science*, 29, 133-147. https://www.tfri.gov.tw/en/News_Content2.aspx?n=7589&s=15125

Zhang, X., Lian, Z., & Wu, Y. (2017). Human physiological responses to wooden indoor environment. *Physiology & Behavior*, 174, 27–34. https://doi.org/10.1016/j.physbeh.2017.02.043

Trade Literature & Whitepapers

Augustin, S., & Fell, D. (2015). Wood as a Restorative Material in Healthcare Environments. (Industry Report, FPInnovations). Retrieved June 24, 2024 from https://www.glass.org/sites/default/files/2020-09/wood_as_a_restorative_material.pdf

Curtis, C., Hindmarsh-Wilcox, J., Himes, R., McConnel, C., Noriega, I., Orta, E., Legé, A., Dore, I., Meyer, W., Crowell, J., Randall, J., Williams, M., Bell, B., Mammone, T., & Woodhouse, K. (2022). Mass Timber Schools: Building for Wellness. (Report, Mithun Architects). Retrieved June 21, 2024 from https://mithun.com/wp-content/uploads/2021/12/MassTimberSchools_Report.pdf

Knox, A., & Parry-Husbands, H. (2018). *Workplaces: Wellness + Wood = Productivity*. Pollinate. (Industry Report, Forest Wood Products Australia) Retrieved June 24, 2024 from https://fwpa.com.au/report/workplaces-wellness-woodproductivity/

Lowe, Graham. (2020). Wood, Well-being and Performance: The Human and Organizational Benefits of Wood Buildings. (industry Report, Naturally Wood). Retrieved June 18, 2024, from https://www.naturallywood.com/wp-content/uploads/wood-well-being-and-performance_report_graham-lowe.pdf.

Stora Enso. (n/d). 10 reasons why wooden buildings are good for you. (Industry Report, Stora Enso). Retrieved June 21, 2024 from https://www.storaenso.com/en/products/wood-products/wood-house-effect

ThinkWood. (2019). Wood and Indoor Environment Creating Beneficial Spaces for Living, Working, Well-Being. (Industry Report, ThinkWood). Retrieved June 21, 2024 from https://www.thinkwood.com/wp-content/uploads/2019/08/Think-Wood-CEU-Wood-and-Indoor-Environment.pdf

TRADA. (n/d). The role of wood in healthy buildings. (Industry report, TRADA). Retrieved June 21, 2024 from https://www.centrumhout.nl/wp-content/uploads/2022/06/trada-briefing_healthy-buildings.pdf

Wood2New. (2017). Competitive wood-based interior materials and systems for modern wood construction. (Report, WoodWisdom-Net Research Programme). Retrieved June 21, 2024 from https://www.aalto.fi/sites/g/files/flghsv161/files/2020-01/wood2new_final_report_0.pdf

WO2. (n/d). Une nouvelle qualité de vie. (Industry website, WO2). Retrieved May 16, 2024 from https://www.wo2.com/nouvelle-qualite-de-vie

Zingerle P., Beikircher W., Philippe M., Flach M. (2015). BIGCONAIR – Baubiologische Containerentwicklung für hochwertige Holzmodule in Containerform – Probandenstudie as cited in Bodemer, E., Kleinhenz, M., Erhard, L., & Winter, S. (n/d). Gesundheitliche Interaktion von HOLZ – MENSCH – RAUM. Informationsdienst Holz. Retrieved June 21, 2024 from https://informationsdienst-holz.de/fileadmin/Publikationen/10_Verbraucherinformationen/HOMERA.pdf