# The Use of Wood Betters the Relationship Between People and Places

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ABSTRACT: *Wood is a very versatile building material. For centuries it has been used in construction. The use of wood declined as the use of reinforced concrete increased. Wood is a renewable material capable of storing $CO_2$, which is helpful for the struggle against climate change. Thus, starting from proper forest management, it is possible to have a building material that suits indoor climate conditions, allowing the improvement of structural response, good thermal and acoustic insulation, excellent olfactory perception, and easy humidity control. This versatility makes it a great material to ensure the well-being and comfort of the user. Well-being and comfort are people's perceptions of their environmental conditions. People's expectations and experiences are vital to the success of bio-economy business strategies, even if the inclusion of the human dimension is often not considered in the resolution of problems relating to housing. The focus of this paper is the encouragement of using wood, notably engineered woods like cross-laminated timber (CLT), glued laminated timber (glulam), nail laminated timber (NLT) and dowel laminated timber (DLT), because it favors the relationship between people and spaces, and it guarantees an excellent response in structural terms. This triggers a virtuous mechanism that enhances the entire wood supply chain that starts from forest management and reaches the benefits of the user both in the residential dimension and in the global space.*

KEYWORDS: comfort indoor, wood, CLT, indoor environmental quality, bio-economy.

## INTRODUCTION

The use of wood betters the relationship between people and places: as a building material, it reduces the stress of occupants and is perceived as natural and warm (Frontczak et al., 2012); as interior finishes, it positively influences the comfort evaluation of space (Watchman et al., 2017). Despite the consumer's great importance, wood's effects on occupants' comfort have been rarely documented in built environments. The definition of internal comfort has an interdisciplinary nature that encompasses the psychology, physiology, and thermal-physics of buildings (Legros et al., 2020; Tian et al., 2018). An optimal quantity of wood in interior environments may exist because natural materials, such as stone, brick, and wood, convince the observer of their authenticity related to their age and history. In contrast, synthetic materials do not convey their essence or age to the observer. Well-being and comfort are people's perceptions of the environmental conditions they find themselves. People's expectations and experiences are vital to the success of bio-economy business strategies (Toppinen et al. 2018; Caru A. and Cova B. 2007), but the inclusion of the human dimension is often not considered in the resolution of problems relating to housing (Gram-Hanssen, 2014). People base their choices on social, cultural, economic, and psychological aspects (Wilk, 2002) in addition to aesthetics, well-being, and respect for the environment (Gold & Rubik, 2009; Hakala et al., 2015; Larasatie et al., 2018; Roos & Hugosson, 2008) but rarely on technical ones. Today, wood is again appreciated thanks to its natural features and the capacity to store $CO_2$. Wood could be a building material since it promotes the improvement of the structural response of buildings reducing the weight of the structure, has good thermal properties and allows satisfactory olfactory perception and easy control of humidity. The encouragement of using wood, and in particular, engineered wood like cross-laminated timber (CLT), favors the relationship between people and spaces and, at the same time, guarantees an excellent response in structural terms and better comfort to users. Its use triggers a virtuous mechanism that enhances the entire wood supply chain that, starts from forest management and reaches the benefits of the user both in the residential dimension and in the global space.

## 1. INDOOR COMFORT

Well-being and comfort are people's perceptions of the environmental conditions in which they are. Objective and subjective factors influence these perceptions and produce a reaction in the organism. Comfort is a subject that has been much studied in recent decades, considering the effect that it can have on human health (Baloch et al. 2020). However, its interdisciplinary nature creates a lack of a general definition.

One of the main parameters that deeply influences comfort is the thermal condition of an environment. Measurable and objective parameters define indoor thermal comfort:

- Air temperature. The optimal ranges vary from 19 °C to 22 °C in winter and from 24 °C to 26 °C in summer. It is preferable to have a homogeneous temperature in all the rooms.
- Air humidity. The optimal relative humidity values in a domestic environment should be between 40% and 50% in winter and between 50% and 60% in summer (UNI/TS 11300-1, 2014). Too dry environments damage the protective mucous membranes of the respiratory system, while those that are too wet favor the proliferation of viruses, bacteria and moulds.
- Air speed. The air currents, both hot and cold, generate physical intolerance. The air velocity in a house should be 0.01- 0.1 m/s in winter and 0.1-0.2 m/s in summer.
- Operating temperature ($T_{op}$), defined in ISO 7726 (ISO 7726, 1998). It considers the thermal exchanges between the human body and the surrounding environment by convection and radiation. It is the uniform temperature of an imaginary black envelope with which an occupant would exchange the same amount of heat as the actual room at an uneven temperature. It is determined by equation (1):

$$T_{op} = \frac{h_r * T_{mr} + h_c * T_{air}}{h_r + h_c} \quad (1)$$

where

- $h_r$ is the coefficient of radiation heat exchange
- $h_c$ is the coefficient of convective heat exchange
- $T_{mr}$ is the average radiant temperature
- $T_{air}$ is the air temperature.

Thus, the temperature perceived by the occupant depends on the air temperature and the surrounding surface temperatures.

The indoor environmental quality is also affected by the following:

- Air quality. It is determined by the presence or not of various physical, chemical, and biological contaminants. When these pollutants are present in significant quantity, the body reacts with symptoms of the respiratory tract, but also with other types of somatic pathologies, such as eye irritation and allergies.
- Olfactory perception. It can be associated with a pleasant or unpleasant smell. The sense of smell often determines decisions and behaviours. Olfactory perception can improve or worsen our well-being in an environment.
- Visual perception. It can blend the boundaries between indoor and outdoor spaces, between materials inside a built environment and its relationship to the materials in the landscape outside.

In addition:

- The optimal condition of visual comfort is obtained with natural light, but in the absence of this, it is good to maintain an adequate brightness resulting from more points of light in each room, to improve visual well-being. In a dwelling, visual comfort is given by points of light distribution, colour rendering, light shades, distribution of shadows, light direction, luminance distribution, and limitation of glare.

Moreover, the high visual relationship between the interior and the exterior is a condition that optimizes visual comfort.

- Sound/acoustic comfort depends on both internal and external sound sources. In a house, a good level of sound intensity is around 50 dB and can be achieved with efficient sound insulation.

## 2. THE ADVANTAGES OF USING WOOD

Until a few years ago, making a home comfortable was synonymous with higher energy expenses due to air conditioning and electrical devices, but today the concept of living comfort goes hand in hand with energy saving (Legros et al., 2020). This is mainly due to the materials used and new construction techniques. The construction sector increasingly uses low-$CO_2$ materials, such as materials of biological origin (wood, engineering wood, cork, straw, hemp, sheep's wool, etc.). Wooden houses, built with cutting-edge methods, tend to optimize the characteristics of environmental comfort thanks to the properties of the natural material used. Furthermore, automated and management systems, able to reduce energy consumption by monitoring the internal conditions, such as controlled mechanical ventilation, home automation systems, etc. can further improve living comfort.

Wood is the most used material for prefabricated houses and can ensure a high level of living comfort thanks to its innate characteristics. Its low thermal conductivity reduces the heat exchange between conditioned/non-conditioned spaces at different temperatures and retains heat inside the building (Ni et al., 2022) favoring thermal comfort conditions. It is an acoustic insulation that protects the house from unpleasant external noise even if timber structures, by their natural flexibility, tend to be characterized by low-frequency noise, which reduces occupant comfort (Gibson et al., 2022; van Damme et al., 2007). Ad hoc solutions are needed to reach the benchmarks set by the standards to ensure adequate living comfort.
Since it is a hygroscopic material (Fig. 1), it naturally regulates the level of internal humidity (Ojanen 2014), improving well-being conditions. Moreover, olfactory perception can be improved, through correct and effective ventilation, both natural and mechanical, and by installing an air exchange system.

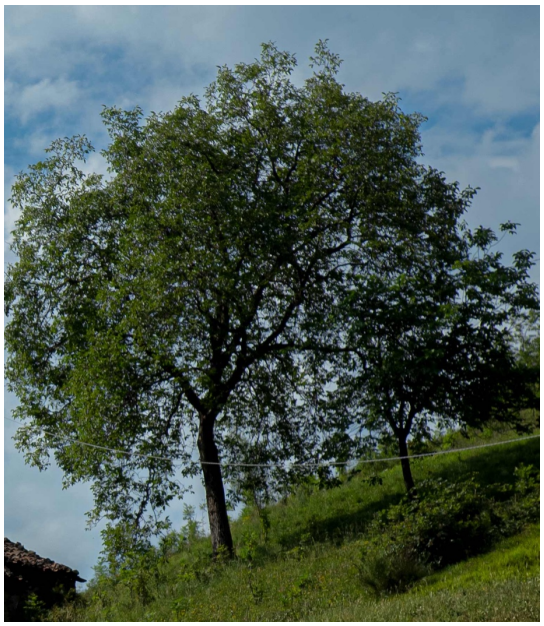
Figure 1: Example of hygroscopic effect: shrinking cracks caused by water leaks.

## 2.1 User satisfaction thanks to the wooden constructions

Several studies have been carried out to determine user satisfaction. In France (Legros et al., 2020), and in Canada (Rice et al., 2007), many people claim that perceived comfort is better inside a wooden room than in a plasterboard one. In fact, rooms made of wood are often evaluated better subjectively than objectively. The comfort temperature for the occupants is affected by the microclimate and some personal factors such as age and gender. On the other hand, the microclimate in a room of a building is also influenced by the materials of the walls. Different materials produce diverse internal temperatures (Hermawan, Prianto, and Setyowati 2020), but age and gender (De Simone & Fajilla, 2019) affect comfort perception. Moreover, considering the air quality, especially in old buildings, an abundance of pathogens and dangerous pollutants (Fürhapper et al., 2019; Pop et al., 2019) may be present.
Another problem related to wood is the growth of microorganisms and fungi. Solid wood buildings can present microbial charge by direct dust deposition due to a complex combination of local environmental conditions (Huniadi et al., 2019; Stenson et al., 2019). Old buildings must be monitored to minimize health risks and optimize maintenance costs, especially if they are historical and of tourist interest. Indoor air quality (IAQ) has become an important research topic in construction. Pollutants are harmful to human health and particularly dangerous for the most vulnerable, such as older people and children. Monitoring and controlling the internal microclimate and air quality through heating-ventilation-lighting are crucial (Marcu et al., 2021).

## 3. BIOECONOMY RELATED TO WOOD INDUSTRIES

The European Union's Bioeconomy Strategy (2018) promotes labels on wood materials to reduce carbon dioxide emissions in the construction sector, thus enabling the transition to a sustainable bioeconomy. The EU's goal towards a biobased circular economy promotes low-land-use construction and the use of recyclable materials and innovative and sustainable technologies. So starting from wood, it is possible to achieve these goals. Wood, by its nature, has characteristics that are often framed as a defect, such as a knot, ring shake, grain and shrinkage slot. The negative characteristics of wood are overcome through engineered wood products which are typically made up of wooden layers glued together or nailed, and they can be used both for new multi-storey wooden buildings (MSWB) and for the improvement of the overall response of existing structures (Frunzio et al., 2021; Frunzio & di Gennaro, 2018; Izzi et al., 2018; Sun et al., 2020). In Europe, interventions in existing buildings are necessary to renew their formal, structural, and technological aspects and preserve land consumption. (Frunzio et al., 2022; Pohoryles et al., 2020; Rinaldi et al., 2021). An example of engineering wood is Cross Laminated Timber (CLT). It consists of laminated wood arranged in cross layers. The solid wood use is typically softwood, but many researchers push to use local wood (softwood and hardwood) to improve the local short wood supply chain although of regulatory limitations on the use of some wood essences (Frunzio et al., 2021; Rinaldi et al., 2021). For example, Italy pushes to use chestnut and beech (Fig.2).


a)

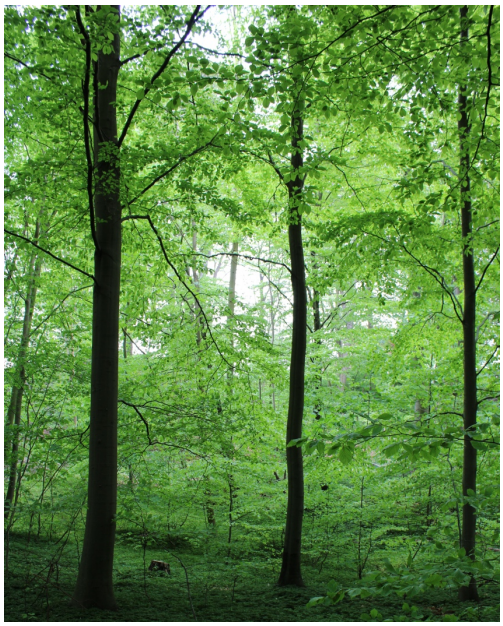

b)

Figure 2: Examples of: a) Castanea sativa (chestnut), b) Fagus (beech).

Consumer acceptance of new bio-based products plays a key role in the transition to the forest bioeconomy (Kylkilahti et al., 2020). The MSWB represent a modern business opportunity based on biological material for the realization of low-CO2 urban housing.

However, there is limited knowledge of consumers' different perceptions of wood as an urban building material. Despite the policy's success in supporting the spread of MSWB, cultural acceptance of MSWB has yet to be determined (Vainio et al., 2019). In addition, it must be taken into account that the environmental considerations of consumers are intertwined with the social, cultural, economic and psychological aspects of consumption (Wilk, 2002). Research into consumer perceptions of housing is necessary to fill these multidimensional aspects even if today, the inclusion of the human dimension, as perceptions and experiences of residents, is often not considered in the resolution of problems related to housing (Gram-Hanssen, 2014). Understanding people's expectations and experiences is vital to the success of business strategies driven by the bioeconomy (Caru A. & Cova B., 2007; Toppinen et al., 2018). In particular, there is limited knowledge about how consumers perceive the use of wood in MSWB. Consumer perception literature on timber as a building material is evolving. Wood can arouse both positive and negative perceptions among consumers. Literature suggests that "soft" factors, such as aesthetics, well-being, and respect for the environment, are features used to evaluate wooden-framed houses among German consumers (Gold & Rubik, 2009). Also, other studies document that consumers are inclined to value wood as a building material, especially considering features such as aesthetic beauty and a comfortable environment (Larasatie et al., 2018). Young people appreciate the wooden interior's aesthetics but also perceive wood as expensive and wonder if wood products are environmentally sustainable (Hakala et al., 2015; Roos & Hugosson, 2008). Overall, concerns

about earthquake safety or resistance are common findings in past studies. But, subjects who were previously familiar with wooden buildings were less likely to consider them susceptible to fire or consider their maintenance too expensive (Kylkilahti et al., 2020). For instance, in Finland, students' perceptions of MSWB are related to their familiarity with wooden residential buildings.
Moreover, the aesthetic appearance of MSWB is appreciated above all by thrifty and responsible consumers. At the same time, comfort, respect for the environment and durability of MSWB are important for consumers who identify themselves as "thoughtful spenders". So, many studies suggest that familiarity with the use of wood in homes, both for young environmentally conscious and "hedonistic" consumers, can contribute to a successful bio-economy in the urban context.

## 4. CONCLUSION

The encouragement of using wood and engineered woods like CLT, NLT, DLT and glulam better the relationship between people and spaces. It blends the boundaries between indoor and outdoor spaces and connects materials inside a built environment and those in the outdoor landscape. It is a flywheel for the entire wood supply chain. Good management of forests allows for high-quality structural wood. Thanks to their choice, the users obtain a twofold benefit: in the residential dimension, they ensure greater comfort in the global space, reducing their carbon footprint.

## REFERENCES


Baloch, R. M., Maesano, C. N., Christoffersen, J., Banerjee, S., Gabriel, M., Csobod, É., de Oliveira Fernandes, E., Annesi-Maesano, I., Csobod, É., Szuppinger, P., Prokai, R., Farkas, P., Fuzi, C., Cani, E., Draganic, J., Mogyorosy, E. R., Korac, Z., de Oliveira Fernandes, E., Ventura, G., … Dewolf, M.-C. (2020). Indoor air pollution, physical and comfort parameters related to schoolchildren's health: Data from the European SINPHONIE study. *Science of The Total Environment*, *739*, 139870. https://doi.org/10.1016/j.scitotenv.2020.139870

Caru A., & Cova B. (2007). *Consuming Experience*. Routledge.

de Simone, M., & Fajilla, G. (2019). Gender-related differences in perceived productivity and indoor environmental quality acceptance. Results of a questionnaire survey in university workplaces. *Journal of World Architecture*, *3*. https://doi.org/10.26689/jwa.v3i4.819

Eriksdotter, G., & Legnér, M. (2015). Indoor Climate and Thermal Comfort from a Long-Term Perspective. *Home Cultures*, *12*(1), 29–53. https://doi.org/10.2752/175174215X14171914084692

Frontczak, M., Schiavon, S., Goins, J., Arens, E., Zhang, H., & Wargocki, P. (2012). Quantitative relationships between occupant satisfaction and satisfaction aspects of indoor environmental quality and building design. *Indoor Air*, *22*(2), 119–131. https://doi.org/10.1111/j.1600-0668.2011.00745.x

Frunzio, G., & di Gennaro, L. (2018). Seismic structural upgrade of historical buildings through wooden deckings strengthening: the case of study of Palazzo Ducale in Parete, Italy. *Procedia Structural Integrity*, *11*, 153–160. https://doi.org/10.1016/J.PROSTR.2018.11.021

Frunzio, G., Di Gennaro, L., Massaro, L., & D'Angelo, F. (2021). THE CLT PANELS IN STRUCTURAL RESTORATION: CHARACTERISTICS AND TECHNICAL REGULATIONS. *12th International Conference on Structural Analysis of Historical Constructions - SAHC 2020*, 2718–2728. https://doi.org/10.23967/sahc.2021.281

Frunzio, G., Rirnaldi, S., Guadaguolo, M., Massaro, L., & di Gennaro, L. (2022). Use of engineered wood for the retrofitting of existing structures. *9TH INTERNATIONAL CONFERENCE ON HARMONISATION BETWEEN ARCHITECTURE AND NATURE - Eco-Architecture 2022*, 225–236. https://doi.org/10.2495/ARC220191

Fürhapper, C., Habla, E., Stratev, D., Weigl, M., & Dobianer, K. (2019). Living Conditions in Timber Houses: Emission Trends and Indoor Air Quality. *Frontiers in Built Environment*.

Gibson, B., Nguyen, T., Sinaie, S., Heath, D., & Ngo, T. (2022). The low frequency structure-borne sound problem in multi-storey timber buildings and potential of acoustic metamaterials: A review. In *Building and Environment* (Vol. 224). Elsevier Ltd. https://doi.org/10.1016/j.buildenv.2022.109531

Gold, S., & Rubik, F. (2009). Consumer attitudes towards timber as a construction material and towards timber frame houses - selected findings of a representative survey among the German population. *Journal of Cleaner Production*, *17*(2), 303–309. https://doi.org/10.1016/j.jclepro.2008.07.001

Gram-Hanssen, K. (2014). Retrofitting owner-occupied housing: remember the people. *Building Research & Information*, *42*(4), 393–397. https://doi.org/10.1080/09613218.2014.911572

Hakala, I., Autio, M., & Toppinen, A. (2015). Young Finnish and German consumers' furniture acquisition - wooden, inherited or just low price? *International Journal of Consumer Studies*, *39*(5), 445–451. https://doi.org/10.1111/ijcs.12189

Hermawan, Prianto, E., & Setyowati, E. (2020). The comfort temperature for exposed stone houses and wooden houses in mountainous areas. *Journal of Applied Science and Engineering*, *23*(4), 571–582. https://doi.org/10.6180/jase.202012_23(4).0001

Huniadi, A., Sorian, A., Maghiar, A., Mocuta, D., Antal, L., Pop, O. L., Judea Pusta, C. T., Buhas, C. L., Pascalau, A., & Sandor, M. (2019). 6-(2,3-Dichlorodiphenyl)-1,2,4-Triazine-3,5-Diamine Use in Pregnancy and Body Stalk Anomaly- A Possible Association? *Revista de Chimie*, *70*(7), 2656–2659. https://doi.org/10.37358/RC.19.7.7399

*ISO 7726:1998 (en), Ergonomics of the thermal environment — Instruments for measuring physical quantities*. (1998). https://www.iso.org/obp/ui/#iso:std:iso:7726:ed-2:v1:en

Izzi, M., Casagrande, D., Bezzi, S., Pasca, D., Follesa, M., & Tomasi, R. (2018). Seismic behaviour of Cross-Laminated Timber structures: A state-of-the-art review. *Engineering Structures*, *170*, 42–52. https://doi.org/10.1016/J.ENGSTRUCT.2018.05.060

Kylkilahti, E., Berghäll, S., Autio, M., Nurminen, J., Toivonen, R., Lähtinen, K., Vihemäki, H., Franzini, F., & Toppinen, A. (2020). A consumer-driven bioeconomy in housing? Combining consumption style with students' perceptions of the use of wood in multi-storey buildings. *Ambio*, *49*(12), 1943–1957. https://doi.org/10.1007/s13280-020-01397-7
Larasatie, P., Guerrero, J. E., Conroy, K., Hall, T. E., Hansen, E., & Needham, M. D. (2018). What Does the Public Believe about Tall Wood Buildings? An Exploratory Study in the US Pacific Northwest. *Journal of Forestry*, *116*(5), 429–436. https://doi.org/10.1093/jofore/fvy025
Legros, C., Piot, A., Woloszyn, M., & Pailha, M. (2020). Effect of moisture buffering on surface temperature variation: study of different indoor cladding materials. *E3S Web of Conferences*, *172*, 06002. https://doi.org/10.1051/e3sconf/202017206002
Marcu, F., Hodor, N., Indrie, L., Dejeu, P., Ilieș, M., Albu, A., Sandor, M., Sicora, C., Costea, M., Ilieș, D. C., Caciora, T., Huniadi, A., Chiș, I., Barbu-Tudoran, L., Szabo-Alexi, P., Grama, V., & Safarov, B. (2021). Microbiological, Health and Comfort Aspects of Indoor Air Quality in a Romanian Historical Wooden Church. *International Journal of Environmental Research and Public Health*, *18*(18), 9908. https://doi.org/10.3390/ijerph18189908
Ni, S., Zhu, N., Zhang, Z., Hou, Y., & Li, S. (2022). The operational performance of net zero energy wooden structure building in the severe cold zone: A case study in Hailar of China. *Energy and Buildings*, *257*. https://doi.org/10.1016/j.enbuild.2021.111788
Ojanen, T. (2014). *Moisture capacity of log houses can improve the indoor climate conditions*.
Pohoryles, D. A., Maduta, C., Bournas, D. A., & Kouris, L. A. (2020). Energy performance of existing residential buildings in Europe: A novel approach combining energy with seismic retrofitting. *Energy and Buildings*, *223*, 110024. https://doi.org/10.1016/j.enbuild.2020.110024
Pop, O. L., Judea Pusta, C. T., Buhas, C. L., Judea, A. S., Huniadi, A., Jurca, C., Sandor, M., Negrutiu, B. M., Buhas, B. A., Nikin, Z., & Pascalau, A. (2019). Anaplastic Lymphoma Kinase (ALK) Overexpression in Lung Cancer Biopsies - An 18 month study in north western Romania. *Revista de Chimie*, *70*(7), 2690–2693. https://doi.org/10.37358/RC.19.7.7407
Rice, J., Kozak, R., Meitner, M., & Cohen, D. (2007). Appearance wood products and psychological well-being. *Wood and Fiber Science*, *38*.
Rinaldi, S., Frunzio, G., Guadagnuolo, M., di Gennaro, L., & Massaro, L. (2021). A sustainable material for sustainable architecture: wood in parasite architecture. *XVII International Conference on Building Pathology and Constructions Repair, (CINPAR)*, 481–488. https://doi.org/10.4322/cinpar.2021.061
Roos, A., & Hugosson, M. (2008). Consumer preferences for wooden and laminate flooring. *Wood Material Science & Engineering*, *3*, 29–37.
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*. https://doi.org/10.3390/buildings9060142
Sun, X., He, M., & Li, Z. (2020). Novel engineered wood and bamboo composites for structural applications: State-of-art of manufacturing technology and mechanical performance evaluation. In *Construction and Building Materials* (Vol. 249). Elsevier Ltd. https://doi.org/10.1016/j.conbuildmat.2020.118751
Tian, G., Zhang, H., Feng, Y., Wang, D., Peng, Y., & Jia, H. (2018). Green decoration materials selection under interior environment characteristics: A grey-correlation based hybrid MCDM method. In *Renewable and Sustainable Energy Reviews* (Vol. 81, pp. 682–692). Elsevier Ltd. https://doi.org/10.1016/j.rser.2017.08.050
Toppinen, A., Autio, M., Sauru, M. E., & Berghäll, S. (2018). Sustainability driven new business models in wood construction towards 2030. In *Towards a Sustainable Bioeconomy: Principles, Challenges and Perspectives* (pp. 499–516). https://doi.org/10.1007/978-3-319-73028-8_25
UNI/TS 11300-1 Energy performance of buildings Part 1: Evaluation of energy need for space heating and cooling, (2014).
Vainio, A., Ovaska, U., & Varho, V. (2019). Not so sustainable? Images of bioeconomy by future environmental professionals and citizens. *Journal of Cleaner Production*.
van Damme, M., Blasco, M., Crispin, C., Huart, P., & Wuyts, D. (2007). *Acoustic Comfort In Timber Frame Dwellings* (Vol. 14). www.bbri.be
Watchman, M., Potvin, A., & Demers, C. M. H. (2017). A post-occupancy evaluation of the influence of wood on environmental comfort. *BioResources*, *12*(4), 8704–8724. https://doi.org/10.15376/biores.12.4.8704-8724
Wilk, R. (2002). Consumption, human needs, and global environmental change. *Global Environmental Change*, *12*(1), 5–13. https://doi.org/10.1016/S0959-3780(01)00028-0