NZ WOOD
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NZ Wood Design Guides

SOCIAL AND HEALTH BENEFITS OF TIMBER CONSTRUCTION

Chapter 2.2 | February 2020

Wood Processors & Manufacturers
Association of New Zealand

NZ Wood Design Guides

A growing suite of information, technical and training resources, the Design Guides have been created to support the use of wood in the design and construction of the built environment.

Each title has been written by experts in the field and is the accumulated result of years of experience in working with wood and wood products.

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- Timber, Carbon and the Environment
- Seismic Design of Timber Buildings
- Holes, Notches and Cutouts
- Post and Beam Buildings
- Working Safely with Prefabricated Timber
- Structural Forms and Exemplars

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NZ Wood Design Guides is a Wood Processors and Manufacturers (WPMA) initiative designed to provide independent, non-proprietary information about timber and wood products to professionals and companies involved in building design and construction.

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INTRODUCTION

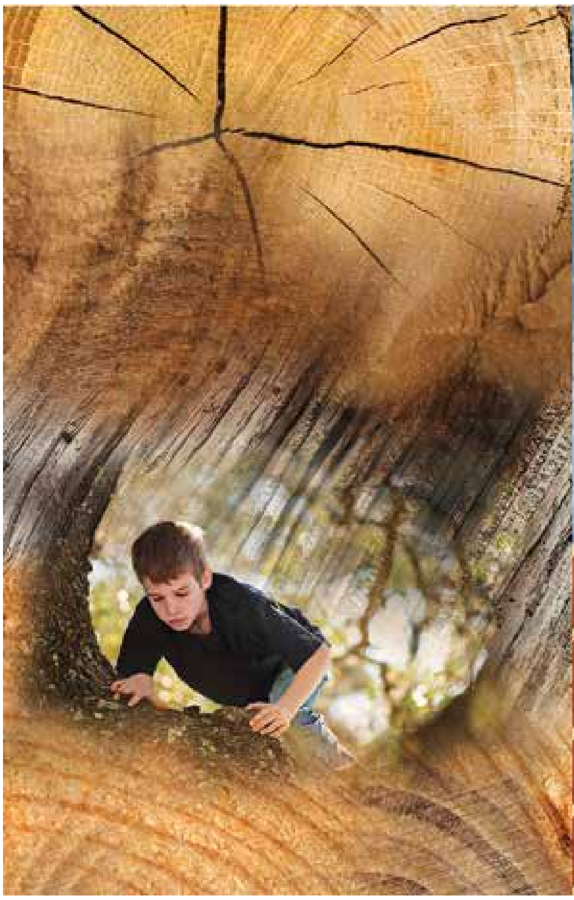
Although wood has ancient origins and has been used in every culture in the world since before the Stone Age it is experiencing a revival in use. In recent years timber has undergone a renaissance and is now emerging as the building material of the future, driven by new technologies and construction methods and its role in limiting greenhouse gas emissions.

Responsibly sourced and certified wood is now seen as an important tool in combating the risks of climate change. However, the use of wood in the built environment is also being increasingly used for its positive impacts on health, wellbeing and productivity, producing similar effects to those created by spending time in outside in nature.

This guide will highlight the significant environmental benefits that building with wood can provide – it's renewable, it stores carbon for the life of the building, and has much less embodied carbon than conventional building materials like concrete and steel – and also provide a deeper understanding of the reasons why using wood and the incorporation of biophilic design principles has a large part to play in the creation of healthy buildings for us to live, work, learn and recover in.

For additional information, please refer to Design Guide Chapter 2.1: Sustainability – Timber, Carbon and the Environment.

1. TIMBER REINVENTS ITSELF



Wood comes from trees and is a natural, renewable resource, with no two pieces being identical. Its final appearance is dependent on a number of variables, including species, geographic area where the tree grew, growth conditions, size of the tree at harvest, sawing and other manufacturing processes. Wood is one of the oldest building materials used by humanity and with recent technological developments it is also one of the most modern.

Timber has traditionally had many uses as a building material, including framing, flooring, fixtures and features. More recently it has become the primary structural component in multi-level construction using engineered timber components, such as cross-laminated timber (CLT), glued laminated timber (glulam) and laminated veneer lumber (LVL).

1.1 ENVIRONMENTAL IMPACT OF CONSTRUCTION

Currently, the global construction and building sector has been estimated to account for:

- 42 per cent of total energy consumption
- 35 per cent of total greenhouse gas emissions
- 50 per cent of extracted materials
- 30 per cent of water consumption

These figures include the whole lifecycle of buildings, from the extraction of raw materials and manufacture of construction products to their decommissioning. Most of the emissions are caused by heating and cooling in the period when a building is in use (operational energy) although the relative impact of the embodied energy (hereafter referred to as embodied carbon) resulting from the construction of a building is increasing as buildings become more energy efficient.

Building and construction is one of the sectors causing the most significant depletion of the earth's natural resources.

The resource intensity of construction means that 'circular thinking' will need to become increasingly accepted in the sector. A 'circular economy' aims for a closed system by maximising the circulation of product flows by reducing material input and waste, and increasing the prevalence of recycling, reuse, and sharing (see chapter 5).

1.2 REDUCING THE CARBON FOOTPRINT OF BUILDINGS

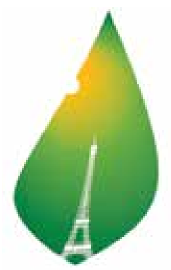
The resources we extract from the earth and manufacture into materials used in the construction of buildings contribute substantially to global CO_2 emissions. As a result it's important to understand the reasons for these impacts, and to implement the best options to reduce these emissions.

For a little over a century the choice of construction materials, particularly for larger-scale commercial projects, has been dominated by concrete and steel. The concrete and steel industries have programs in place to reduce their carbon footprints, and cement substitutes are also becoming more commonplace. However, cement production as a whole currently accounts for around 7 to 8 per cent of global CO_2 emissions. Whilst the recycling of concrete offers increasing scope for uptake, the core issue of carbon emissions from cement production itself still needs to be dramatically reduced.

Similarly, the iron and steel industry has also improved its energy efficiency over recent years, but still accounts for approximately 6 to 7 per cent of global CO_2 emissions. Of course steel can be recycled, which studies show to be typically 35 to 40 per cent of steel used globally. These figures are likely to increase as we transition into a low carbon circular economy, in which high-embodied carbon materials like steel can theoretically be repurposed indefinitely.

The Inter-governmental Panel on Climate Change (IPCC, 2018) has stated that: "In the long term, a sustainable forest management strategy aimed at maintaining or increasing forest carbon stocks, while producing an annual sustained yield of timber, fibre or energy from the forest, will generate the largest sustained mitigation benefit. Given the high carbon footprint of cement and steel production and the challenges these industries continue to face, responsibly sourced timber as a major building material is becoming a compelling third option."

1.3 PARIS CLIMATE CHANGE AGREEMENT



The Paris Climate Change Agreement commits all signatory nations to transition to net zero emissions globally in the second half of this century. For developed countries like New Zealand, this implies a transition to a zero net emissions economy by around 2050.

Specifically, the Paris Agreement requires countries to: i) keep global warming under 2 degrees, and to strive for under 1.5 degrees; ii) develop mid-century decarbonisation strategies, and iii) upgrade national emissions reductions targets every five years. The next international conference is due to take place in 2020 when signatory countries will be called upon to demonstrate progress towards reducing emissions.

1.4 WHY IS TIMBER GOOD FOR THE ENVIRONMENT?

The IPCC (2019) has issued a stark warning about how long we have left to moderate CO_2 emissions and to halt global warming. The report states that it is no longer enough to reduce emissions, rather, it is imperative to start actively reducing the CO_2 already in the atmosphere. The planting of more trees is the only realistic method of reducing atmospheric carbon but, in New Zealand and around the world, moves to encourage more forests and plantations are failing to generate anywhere near the levels required. Furthermore, science confirms that trees are only really effective at carbon absorption during the growth stages. Once they mature, the wood needs to be harvested and new trees planted, supported by the active use of certification schemes like FSC and/or Responsible Wood (PEFC).

1.5 WOOD HELPS TACKLE CLIMATE CHANGE

Wood is the only building material that helps tackle climate change. The use of wood provides three significant environmental benefits; i) it is renewable, ii) it stores carbon for the life of the building, and iii) wood has much lower embodied carbon (also referred to as embodied energy) than conventional, more carbon-intensive building materials like concrete and steel.

1.5.1 Wood is renewable

Wood is the only widely used renewable building material currently available. Planet Ark Environmental Foundation refers to a concept called "Ecological Footprinting" – living on nature's interest, not its capital. In a Yale University study (Oliver et al, 2014) the researchers concluded that the world's forests contain a total volume of wood of 385 billion cubic metres. They also found that an additional 17 billion cubic metres is grown every year, of which we consume 3.4 billion cubic metres, about 20 per cent of the *additional growth*. Hence, using wood we are building using nature's interest, not its capital.

By way of an example the tallest timber building in the world was, until April 2019, a university residence building in Vancouver, Canada known as Brock Commons (shown above). It is 18 storeys or 53 metres tall, and incorporates 2,233 cubic metres of CLT and glulam in its structure. Calculations have shown that the volume of timber used in the building will be regrown in US and Canadian forests in a mere six minutes.

Recommended rotations for forestry harvests typically range from 35 to 70 years, depending on the species and location (compared to one or two rotations per year for most cereal crops). As such, changes to forests can undoubtedly impact society, ecology and the environment. However, even the longest forestry rotations are extremely short compared to geological time scale, that is the time scale for the replenishment of the earth's resources (e.g. rocks, ores and soils) required in the production of other construction materials. In that regard, timber is the only widely used building material that can be considered to be truly renewable.

1.5.2 Wood stores carbon

Trees sequester carbon dioxide (hereafter referred to as CO_2) in standing forests through the process of photosynthesis and store the carbon (so-called 'biogenic carbon') in wood-based products for the life cycle of the product. Approximately half of the dry weight of wood is biogenic carbon, which is stored for as long as the building exists.

For every cubic metre of responsibly sourced radiata pine at a moisture content of 12 per cent that is used in building construction, on average this equates to **800kg** (0.8 tonne) of sequestered CO_2 that has been removed from the atmosphere and stored as **218kg** of biogenic carbon (i.e. 800kg ÷ 44/12* = 218kg) in a cubic metre of timber. (* 44/12 is the ratio of atomic weights for CO_2 and carbon. Hence, for every kilo of biogenic carbon that is stored in timber products, 44/12 = **3.67kg** of CO_2 has been removed from the atmosphere.)

For additional information, please refer to Design Guide Chapter 2.1: Sustainability – Timber, Carbon and the Environment.

When wooden products are used in the construction of buildings, they provide long-term carbon storage. The oldest timber building in the world is the Horyuji Temple in Japan, which has been storing timber since 710, over thirteen hundred years.

1.5.3 Wood has low embodied carbon

Embodied carbon, also referred to as 'embodied energy' or, more recently, 'upfront carbon emissions', is the combined impact of all greenhouse gas emissions attributed to a building material during its life cycle. This cycle encompasses raw material extraction, manufacturing, construction, maintenance, and end-of-life disposal. Embodied carbon has been defined as, 'CO_2 emissions that are generated from the formation of buildings, their refurbishment and subsequent maintenance'.

Using wood significantly reduces the greenhouse gas emissions that are produced during the building's construction phase when compared to conventional materials like concrete and steel, which have significantly higher levels of embodied carbon.

Historically, most of the emissions from buildings were caused by operational energy consumption, mainly to provide heating and cooling. However, with stricter energy efficiency requirements becoming increasingly the norm, the relative importance of the CO_2 emissions as a result of the manufacture of building products (i.e. embodied carbon) is continuing to rise. The total life cycle energy ratio of buildings was previously assumed to be around 80 per cent for operational energy and 20 per cent for embodied energy, but this is now thought to be closer to a 60 per cent to 40 per cent ratio.

Ultimately, the more we build using responsibly sourced timber, the more CO_2 we can sequester from the atmosphere and store as biogenic carbon in the building, and the more embodied carbon can be reduced, which in turn will create an increased demand for timber that will help drive reforestation and afforestation.

The built environment is the primary source of greenhouse gas emissions in many parts of the world, including New Zealand and Australia. It is becoming increasingly important to both understand and decrease the greenhouse gas emissions created by the building and construction sector. Using more wood in construction undoubtedly has the potential to significantly reduce the impact of climate change.

1.6 THE TIMBER RENAISSANCE

Wood used to be the dominant building material across much of the world, but that has declined significantly in recent centuries. In medieval Europe stone and brick began to replace timber, especially in larger, more ornate buildings. More recently, the widespread uptake of concrete and steel have further eroded the role of timber.

In recent years timber has undergone a renaissance and is now emerging as the building material of the future, driven by new technologies and construction methods and its role in limiting greenhouse gas emissions.

Timber construction is currently being revolutionised by a range of materials known collectively as engineered wood products, also known as mass timber, including CLT, glulam and LVL. These products are manufactured by bonding smaller pieces of wood to make a composite unit. Compared to traditional sawn timber, they are stronger, more uniform and can be designed to reduce damage and decay. They can be used to build a much wider range of buildings than sawn timber, including high-rise buildings. As a result, architects and engineers around the world are rapidly extending the possibilities of what can be achieved with timber construction.

1.7 OTHER DRIVERS FOR THE RESURGENCE OF TIMBER AS A BUILDING MATERIAL

1.7.1 Urban densification

As major cities look to increase the number of people living in urban areas, repurposing old office buildings for residential use and the addition of new floors may provide a compelling opportunity as an urban densification strategy. The use of wood brings some significant advantages to this process: i) adding vertical extensions to existing buildings becomes more feasible with timber's lighter weight; ii) building across existing infrastructure (e.g. roads or railways) where transfer structures are required, timber's lighter weight means reduced transfer loads and associated structural costs; and iii) timber's lighter weight is also an advantage when building on sites underlain by poor foundation material.

1.7.2 Offsite prefabrication

Prefabricated buildings are made up of component parts manufactured in remote factories, transported to site, and assembled into whole buildings. There are numerous benefits of offsite prefabrication, including faster construction times, less waste, reduced noise, dust and site disruption and improved occupational health and safety.

In addition, the benefits of prefabrication in mass timber include greater accuracy of machined components, easier factory handling, transportation and onsite erection due to its light weight, and wood machining processes that are ideally suited to Building Information Modelling (BIM) and Computer Numerical Control (CNC) technology.

For additional information, please refer to Design Guide 5.1: Designing for Prefabrication.

1.7.3 Reduced installation time

Timber's faster construction speed results mostly from its light weight which allows larger and fewer lifts, dry jointing of components on site, fewer and stronger joints and precise sequential packing and delivery of components to provide a highly time-efficient construction process.

For the construction of larger, multi-storey buildings engineered timber components are typically prefabricated offsite which can provide a significant reduction in onsite construction time. A major advantage in using timber rather than wet pour concrete is the elimination of set and dry times, thereby reducing the construction program and allowing other trades to begin work sooner.

1.7.4 Lower cost of construction

Comparative studies of the economics of different wall framing systems indicate that, in terms of direct building expenses, timber frames are consistently the most cost-effective solution. Research and analysis has also showed that larger-scale, commercial timber buildings can be 10-15 per cent more cost effective to construct than more conventional construction methods across many building types.

There are a number of factors which helps to reduce the cost of timber construction compared to traditional building materials, including: i) reduced construction time; ii) wood's lighter weight can reduce foundation requirements and hence reduce foundation costs; iii) offsite prefabrication usually means that less workers are required on site; iv) scaffolding may not be required (timber structures can often be constructed with safety hand rails already attached to floor panels or cassettes, which removes the need for traditional scaffolding to the outside of the building); and v) it is often possible to use smaller and lighter cranes than would be required for traditional construction.

Potentially the most significant cost savings can be made with a timber construction system in the area of preliminary costs. Therefore, when considering a cost plan for a timber structure, it is important that a detailed investigation of the preliminary costs is provided. Considering only installed material costs ignores significant savings that can be made with timber construction systems.

1.7.5 Performance in seismic zones

The inherent lightness and ductility that wood structures can provide make it a compelling option for construction in earthquake-prone areas, which have been proven to perform well in many parts of the world, including New Zealand. In an earthquake, the force imposed on the structure by shaking depends largely on its mass, with heavier structures experiencing larger seismic forces. Conversely, light timber structures are subject to much smaller destructive forces. The seismic performance of timber structures is an ongoing, active area of research, including full-scale shaking testing of multi-storey frame and CLT buildings.

The Kaikoura District Council Building, a combination of structural engineered wood products and engineering innovation allowed it to withstand the Kaikoura Earthquake event and moreover to become the civil defence headquarters to coordinate the rescue operation.

1.7.6 Timber buildings can be disassembled and relocated at end-of-life

For timber buildings, including traditional timber frame buildings, disassembly and relocation at end-of-life is a viable option, and it is anticipated that this will potentially become more commonplace with the increasing use of glulam beams and columns and CLT floor and wall panels. The methodical installation of prefabricated mass timber elements lends itself perfectly to an equally methodical process of deconstruction, as the elements can simply be separated by removing the screws and fixing plates, which can be done without causing damage to the mass timber components.

1.7.7 Use of recycled timber

Recycled wood can be salvaged from demolished houses, bridges, sheds, factories, warehouses, wharves, boats and other wood products. Using recycled wood extends the life of the wood so there is no need to use newly sourced wood or an alternative building material. In addition, the biogenic carbon contained in recycled wood continues to be stored for the life of the new installation.

The premium price that can be obtained for recycled timbers, particularly hardwood timbers like spotted gum and ironbark, is a major economic factor that helps to ensure recycled timbers re-enter the building market. Increasing landfill costs are also helping to reduce the amount of reusable timber ending up in landfills.

1.7.8 Architectural design flexibility

Timber can provide a high level of architectural design flexibility and options without sacrificing structural requirements. In addition to structural uses, wood provides an excellent architectural material for furniture and other decorative applications, and can be used in many forms such as solid wood, and wood-based composites such as plywood, particleboard and medium density fibreboard.

1.7.9 Natural warmth and timeless beauty of timber

The natural warmth and timeless beauty of timber can provide a structural system and a decorative feature in the one element. Research shows that wood is generally viewed positively and evokes feelings of warmth, comfort, relaxation and is reminiscent of nature. Whilst wood is available with an almost infinite variety of natural colours and patterns, the predominantly yellow-red hue with relatively low contrast is commonplace, and is seen to project a positive, agreeable and pleasant image.

Interestingly, the presence of knots in wood products highlights cultural differences in our perception of it as a pleasing material. In Japan, the presence of knots in wood is considered to diminish its purity and attractiveness, whereas in North America knots are considered to provide a natural and rustic charm.

1.8 PERCEIVED BARRIERS TO THE SELECTION OF WOOD AS A STRUCTURAL MATERIAL

The main perceived barriers that typically need to be addressed regarding the use of wood in construction are; i) flammability, ii) durability, and iii) its potential impact on deforestation. (These issues are discussed in greater detail in sections 2.3, 2.4 and 2.5.)

1.8.1 Flammability

A common concern raised in regard to the use of wood as a building material is whether or not there is an increased risk of fire. Engineers and fire researchers have a significant body of knowledge of how timber constructions perform in fire. The structural stability of timber in the event of fire is well understood and, importantly, it is predictable, allowing timber constructions to be created that meet the same fire safety codes as steel and concrete buildings.

Heavy timber constructions have an inherent level of fire resistance. This resistance increases with the thickness of the wooden elements because when timber is exposed to fire the outer layer turns to char. Charring creates a protective layer that acts as insulation and delays the onset of heating for the cold layer below. With continued exposure to fire the char layer grows but as the burning rate is highly predictable, the wooden elements can be designed to provide sufficient time for escape or intervention.

1.8.2 Durability

Wood is a durable material for both homes and commercial buildings. When properly maintained it can last hundreds of years. Modern wood preservatives can be used to enhance natural durability. Wood has been used for thousands of years and is resistant to heat, frost, corrosion and pollution. The only factor that needs to be controlled is exposure to weathering. Problems with rot and termites are generally the result of poor attention to design and/or construction details, which can unintentionally expose the wood to moisture and sunlight, or inappropriate timber specification.

1.8.3 Deforestation

The increased use of responsibly sourced wood from well-managed, certified forests and plantations provides an effective response to climate change and is likely to be driver for more certified wood building products and drive improvements in forest and plantation management in New Zealand and globally. These positive outcomes can only be achieved by the continued move towards better forestry practices and educating consumers and the design and building industry about the many benefits that can be gained by the use of wood. The fact that Europe’s forests have expanded over the last 20 years despite the significant increase in the use of wood in the building and construction sector is a sign that this is also possible in New Zealand.

2. SOCIAL PERCEPTIONS OF TIMBER BUILDINGS

As a natural building material with unique features, wood creates warm and a pleasant atmosphere and has the potential of enhancing the wellbeing of occupants (see chapter 4).

Research in Australia shows that Australians appear to be innately drawn towards wood and identified that increased levels of wood use in office design contributed to greater levels of productivity (Pollinate report - *Workplaces: Wellness + Wood = Productivity*, 2018).

For its 2015 paper *Wood – Housing, Health, Humanity*, Planet Ark Environmental Foundation conducted a survey where they presented participants with images of two rooms, one furnished with a wooden chair, desk, blinds and other items made from wood, while the other showed the same items made from plastic. Two out of every three people said they preferred the wooden room. This result occurred despite one in two people saying they were completely unaware that wood had associated health benefits.

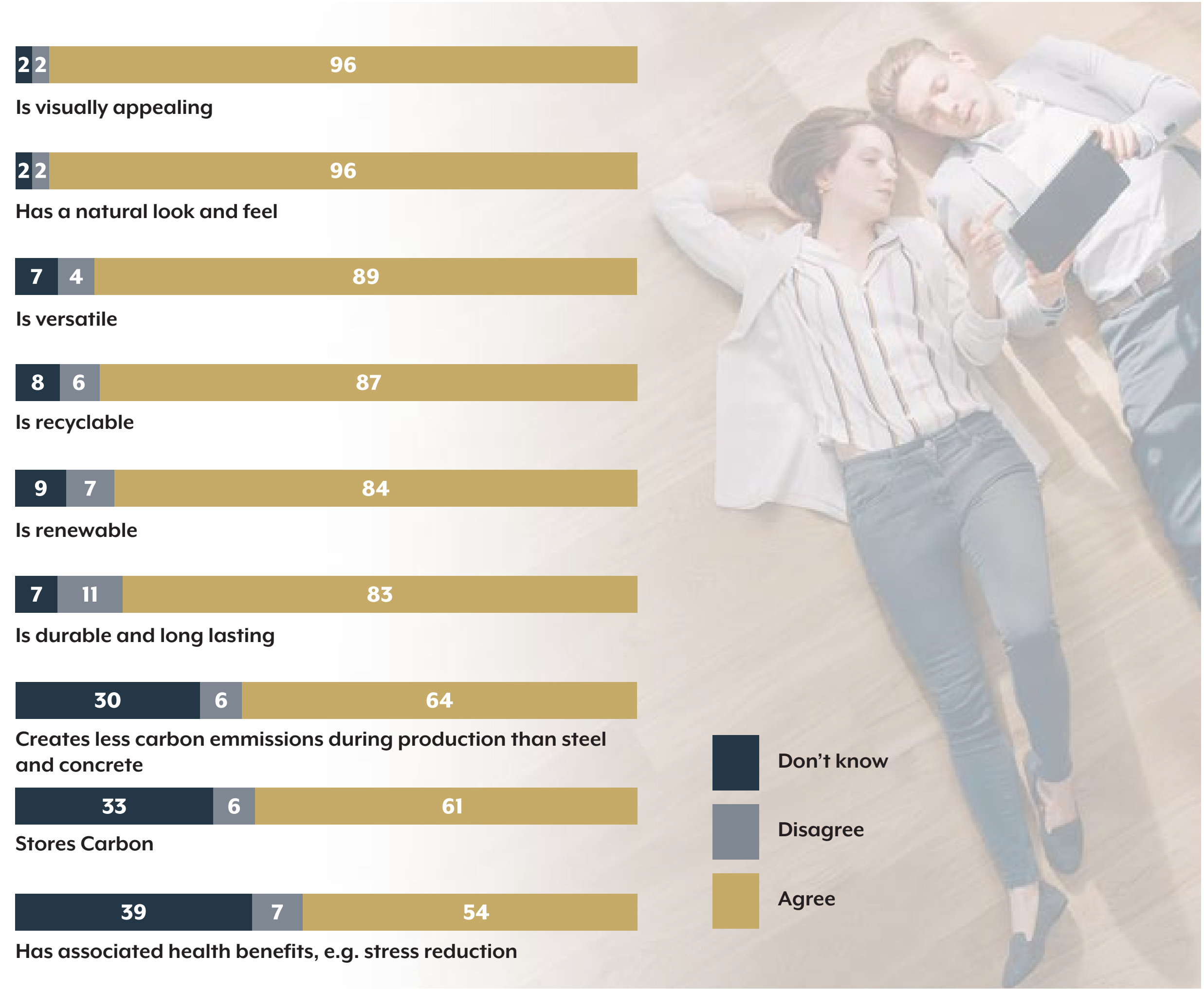


Table 1. Results of a Planet Ark survey on whether participants 'agree', 'disagree' or 'don't know' when asked questions about wood.

Table 1 above highlights the positive associations that wood induces in people, where an overwhelming 96 per cent of survey participants agreed that wood is 'visually appealing' and 'has a natural look and feel'. Eight out of ten people also thought that wood is versatile, recyclable, renewable and long lasting.

Interestingly, the participants appeared to be less aware of the environmental benefits of wood, with only six out of ten survey participants understanding that wood stores carbon and creates less carbon emissions during production than steel and concrete.

MATERIAL	PERCEPTION					
	Creates a natural look & feel	Creates a warm & cosy environment	Visually appealing	Feels nice to touch	Environmentally friendly	Relatively cheap
Wood	93	92	88	87	68	31
Brick	61	62	58	30	47	30
Concrete	25	23	24	20	27	35
Steel	20	16	36	36	28	20
Aluminium	17	15	33	34	30	36
Plastic	14	18	24	36	14	71

Table 2. Results of a Planet Ark survey asking how participants perceive different material types

The positive views of wood continue even when compared to other material types (Table 2). Wood was viewed as a material that creates a natural look and feel, warm and cosy environments, is visually appealing and is nice to touch by nine out of ten people, and as being the most environmentally friendly by seven out of ten people. By comparison the second most popular material, brick, received an average of 34 per cent less positive response. Plastic was seen as the cheapest material, but it also scored lowest in four out of five categories related to creating pleasant surroundings and being environmentally friendly.

These survey results show that even though some of the participants were not aware of the health and wellbeing benefits of wood, they instinctively react positively to the feelings of warmth and comfort it creates and its natural look and feel. An increasing body of research is beginning to show that being surrounded by wood at home, work or school has positive effects on the body, the brain and the environment.

2.1 WOOD CAN MINIMISE THE DISCONNECTION BETWEEN NATURE AND BUILT ENVIRONMENTS

In architectural design, the materials used have the potential to minimise the feeling of disconnection between nature and built environments. Natural interior finishes, such as wood, have the possibility of emphasising the character and attractiveness of a space. A number of studies have focused on the wellbeing of occupants and the indoor use of organic materials, such as wood, and will be expanded upon in chapter 4.

A comparative study of four simulated office environments showed that wood in built environments reduces the stress of occupants and is perceived as natural and warm. A further study found that wood finishes, in comparison with industrial and synthetic finishes, can help to improve the psychological wellbeing of occupants. Participants in another study perceived wood as less modern, industrial, or artificial, and more stylish and contemporary compared with the other materials, and that it exceeded the other finishes as being warm, natural, relaxing, and inviting. Research in Sweden has shown that covering interiors with wooden surfaces can improve indoor environmental quality and thereby affect individuals' health and their psychological and physiological responses. These responses can be generated by improved visual, auditory, olfactory, and tactile stimulation associated with wooden surfaces in interiors (see chapter 3).

2.2 STRUCTURAL USE OF TIMBER

For most of the twentieth century, public perception and prescriptive legislation limited the structural use of timber to small and low-rise structures. The use of timber as a construction material in residential applications is well established in many parts of the world. More recently, the move towards performance-based design has made it possible to build larger and taller timber buildings more routinely, and timber undoubtedly has the fundamental material properties necessary to form large structures.

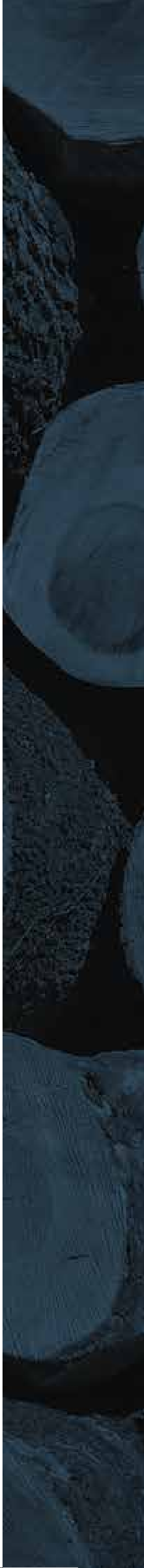
Timber is one of the three most common materials currently used in the construction of large structures, along with steel and reinforced concrete. Arguably, if timber is used in the types of building where it is most structurally efficient, the timber we harvest can do most to reduce the environmental impact of construction.

Timber has a strength parallel to the grain similar to that of reinforced concrete; hardwood is slightly stronger and softwood is slightly weaker. Engineered timber can match concrete in compression stress and is 1/5 of the mass. It has a much lower density than steel, resulting in approximately twice the strength to weight ratio for materials such as Glulam and LVL, which results in a higher level of efficiency when used in long-span or tall structures. A significant part of the load a structure carries is its own self weight.

A growing number of timber buildings of six storeys and above have been built around the world, and building designers are now reviewing the opportunities of producing much taller buildings with timber. In most of these buildings there is also a substantial mass of concrete, primarily used in the ground floor and sub-floor construction, and in some cases as a concrete screed added to the floors to improve acoustic an impulse vibration behaviour.

2.3 FIRE RESISTANCE

The use of timber in larger, multi-storey structures relies on fire engineering design to ensure that the building can retain its structural integrity for sufficient time either for the building occupants to be safely evacuated, or for the fire to be extinguished. In construction using mass timber elements like CLT, this can be done by assuming a rate at which the timber chars, which can then be used to calculate the required cross section of timber remaining at a given time after a fire starts.



Notably, timber structural members are able to perform better at high temperatures in comparison to steel, because the char layer acts to insulate the material underneath it, whereas the high thermal conductivity of steel means that the whole structural section can quickly heat up. In the event of a fire, timber burns in a slow, predictable way, whereas steel can heat up quickly and, at a point that is very difficult to predict, buckle or in some cases fail catastrophically.

An additional benefit of heavy timber is the ease of repair after a fire. The charred sections can be visually assessed and evaluated for residual capacity, and the damaged timber can then be cut away and replaced.

In light timber frame construction the walls and floors are typically encased in non-combustible, fire-protective grade plasterboard to provide protection from fire. This can provide the same level of fire resistance as a completely non-combustible material.

For additional information, please refer to Design Guide Chapter 13.6: Design for Fire Safety.

2.4 DURABILITY AND LIFESPAN OF TIMBER BUILDINGS

Building material durability is typically defined as, "the capability to perform a function over a specified period of time", and in most applications this is normally 50 years.

Lifecycle analysis of buildings assume the same lifespan for timber buildings as other building materials. This assumption is borne out by research which shows that buildings are rarely demolished due to the degradation of their main structure, whatever the structural material. One study which reviewed all of the buildings demolished in Minnesota, USA highlighted that of the 27 wooden buildings that were over 100 years old, none were demolished as a result of a material problem.

2.5 USE OF FORESTS FOR WOOD PRODUCTION

The Global Forest Resources Assessment (FAO, 2015) shows that globally deforestation has slowed and afforestation has increased during the 25-year period from 1990 to 2015. Plantation forests have increasingly provided goods and services previously derived from natural forests, and mosaic forests in agricultural landscapes are increasing. Forest gain is occurring at higher latitudes and in richer countries whilst forest loss continues in poor countries in the tropics. Some middle income tropical countries are now also transitioning to forest gain. These transition countries are characterised by reforms to forest management and improvements in agricultural practices, and also by significant expansions of plantation forest, which account for much of gains.

The global rate of forest loss has decreased since 2010 to about 3.3 million hectares (Mha) or 0.08% annually, approximately half the rate of the 1990s. Forests are stable or expanding in temperate and boreal regions, and the rate of deforestation in the tropics is slowing. Similarly, rates of afforestation are steady or rising not just in temperate countries, where plantation forests have long been integral elements of the forest estate, but also in the tropics where the extent of plantation forests has nearly doubled since 1990.

A significant portion of the global forest estate is already designated for multiple use allowing both production and conservation without prioritising either. Globally 1.049 Mha or one quarter of the forest estate were designated as multiple-use forests in 2015, an increase of 81.8 Mha (8.5%) since 1990.

2.6 MANAGEMENT OF FOREST ECOSYSTEMS AND BIODIVERSITY

In the majority of the global forest estate a high level of emphasis is placed on the management of forest ecosystems for the conservation of biodiversity, including through the creation of reserves, development of management prescriptions, and identification and listing of threatened species.

A growing demand for forest products makes a strong case for expanding plantation forests, including in New Zealand and Australia, which would potentially reduce pressure on natural forests, support biodiversity conservation, and actively reduce atmospheric carbon.

2.7 FOREST AND WOOD CERTIFICATION

Certification ensures that the wood comes from legally harvested and well-managed forests and plantations. Certified forests are managed with environmental, social and economic factors as a priority, and ensure that when a tree is harvested another one is planted in its place. Without certification it can be difficult or impossible to know whether wood was taken illegally or from high conservation value forests.

The two major global forest certification bodies are the Programme for the Endorsement of Forest Certification (PEFC), administered by Responsible Wood in New Zealand and Australia, and the Forest Stewardship Council (FSC). Both PEFC and FSC are internationally recognised forest certification networks that provide for the mutual recognition of regional and national standards that meet their criteria for sustainable forest management.

Internationally around 300 million hectares of forests are certified under PEFC and 195 million hectares under the FSC system. In New Zealand, 1.1 million hectares of plantation forest is certified under the FSC system, and 0.5 million hectares of plantation forest is certified under the PEFC system.

Wood and wood-based products sourced from certified forests are tracked through the supply chain using chain-of-custody certification provided by both forest certification schemes. This provides consumers with an assurance that the wood product they are purchasing comes from a sustainably managed and certified forest. For consumer products these are then labelled with a chain of custody certificate number.

3. HUMAN CONNECTION WITH TIMBER BUILDINGS

(Clockwise) Cathedral Grammar Junior School, Otago Polytechnic Student Village and Shortland Health Clinic.

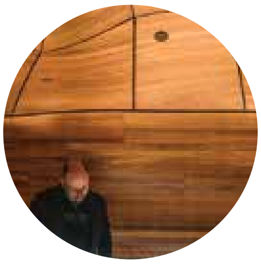
In the 7 million years that the human species has existed, over 99.99 per cent of our evolution has taken place in a natural, outdoor environment. This has continued through the beginning of mass urbanisation dating from the industrial revolution, with a very small amount of time spent in an artificial, urbanised environment. Consequently it's reasonable to conclude that humans are primarily adapted to a natural setting, and research clearly shows that natural environments have a positive effect on our wellbeing.

Moving forward to the twenty-first century, most people spend most of their time indoors and our immediate physical surroundings are known to affect us. Consequently, creating health restoring indoor environments such as offices, hospitals, classrooms, living rooms and bedrooms is an increasingly important aspect of building design. This has resulted in a growing imperative to bring the restorative qualities of nature into these indoor, man-made environments where we spend most of our time. One readily available means to address this is the use of wood as a functional or decorative indoor material.

3.1 PHYSIOLOGICAL RESPONSES TO WOODEN SURFACES

A number of studies have shown that physiological responses to wooden surfaces in interiors are comprised of changes in the activity of the brain, the autonomic nervous system, the endocrine system and the immune system. These changes are caused by the visual, auditory, olfactory and tactile stimulation associated with wooden surfaces in interiors.

3.2 VISUAL STIMULATION



Visual stimulation from a wooden surface is dependent on the colour, structure, surface treatment and the presence of knots. The characteristics of knots vary among different species of tree, including their size, shape, homogeneity, colour, distance between knots and the number of knots on the surface of the wood.

Research has shown that the surface structure of wood generally induces light to scatter and diminish surface glare. Scattering the light in this way can decrease perceived glare and increase luminance value. In general, reduced glare and an adequate luminance value can decrease the incidence of eye fatigue, eye strain and headaches, thereby reducing perceived stress.

The apparent colour of wood depends on the direction of radiated light and the chemical composition of the wood being viewed, including extractives, lignin, cellulose, and hemicellulose. In general, wood emits long-wave light and is therefore perceived as having a predominantly yellow-to-red hue. One part of the radiated light enters the wood cells and is absorbed by voids and pigments, while the other part is emitted through reflection and transmission. Light falling into the eye that has been reflected from interior wooden surfaces can trigger the visual cortex in the brain and thereby affect cognition performance, including analysing, memorising and reasoning processes.

Research highlighted by Jalilzadehazhari and Johansson in 2019 has shown that long-wave colours with a yellow-to-red hue can improve cognitive performance. Furthermore, the aromatic lignin component in wood can absorb a high amount of ultraviolet light, creating a comfortable environment for the eye - ultraviolet exposure can cause degradation of the retina - and multiple studies have highlighted the benefits of the colour of wood on cognition performance and eye health.

Generally, visual stimulation associated with wooden surfaces in interiors was found to have positive effects on physiological responses, which resulted in a reduction in respondents' perceived stress.

3.3 TACTILE STIMULATION

In general, humans acquire most of their knowledge about the physical environment they inhabit through their vision. However, wood in the indoor setting also possesses tactile properties. When wood is used in the indoor environment, people are able to directly touch various wooden materials such as wall and floor finishes as well as wooden columns or furniture.

The effects of tactile stimulation on physiological responses, including skin temperature, generally depend on the heat flux of materials. Heat flux is controlled by the thermal conductivity of materials, and temperature differences between the skin and the material with which it is in contact. The thermal conductivity of wood and wood-based materials is significantly lower than other materials commonly used to cover interiors, such as tile, marble, and concrete, hence less likely to feel either cold or hot.

The well-known Canadian Architect Michael Green has described the way wood affected people in his buildings, saying; "They react completely differently. I've never seen anybody walk into one of my buildings and hug a steel or concrete column. But I've actually seen that happen in a wood building. Just like snowflakes, no pieces of wood can ever be the same anywhere on earth. I'd like to think that wood gives mother nature fingerprints in our buildings."

3.4 AUDITORY STIMULATION

The auditory stimulation from interior wooden surfaces depends mainly on the wood's acoustic performance. Surface treatments including wood stain, clear varnish, and film-forming paint, can affect acoustic performance by modifying damping, stiffness, and mass. In general, wood is considered to have poor acoustic insulation properties when compared with other construction materials. However, sound absorbing panels, such as perforated wooden panels, have been successfully used to absorb sound in interiors, such as cinemas.

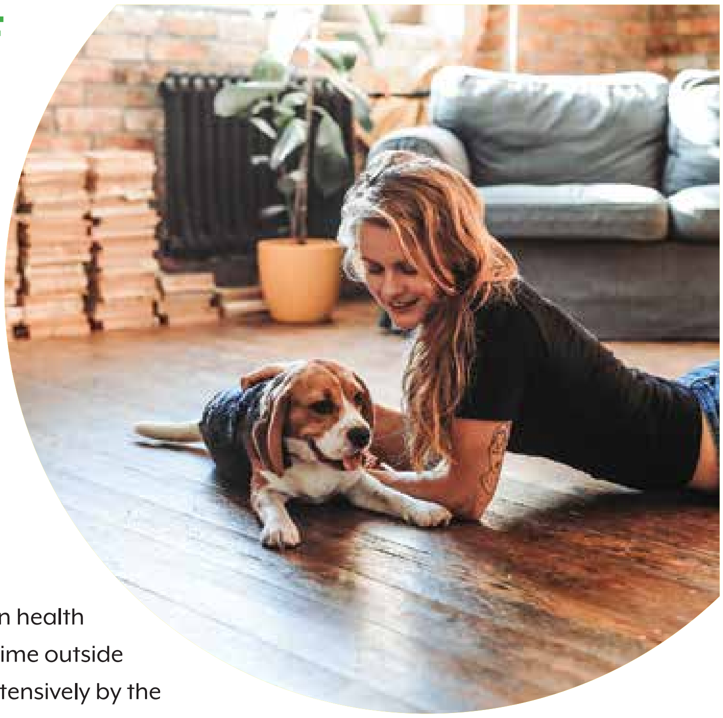
3.5 OLFACTORY STIMULATION

The effects of olfactory stimulation from wood on physiological responses depend strongly on the chemical composition of the wood, including volatile extractives and the subjects' individual differences in sensitivity towards olfactory stimulation. Research to understand the effects of olfactory stimulation from wood suggests that, overall, the smell of wood has a relaxing effect on humans.

3.6 PREFERENCES AND PHYSICAL WOOD PROPERTIES

A number of studies have investigated the relationship between preferences and physical wood properties. In general, these studies have concluded that homogeneous visual properties, essentially wood surfaces with few and evenly dispersed knots and an even growth ring pattern, are preferred by consumers.

4. HEALTH BENEFIT OF TIMBER BUILDINGS



According to the constitution of the World Health Organisation, health is defined as; “a state of complete physical, mental, and social wellbeing and not merely the absence of disease or infirmity”. How humans perceive and interact with their environments can affect their wellbeing, stress levels, and overall health, and, for most people, homes are the environments where they spend most of their time.

Over recent years there has been an increasing recognition of the benefits that humans gain from contact with trees and nature. The improvements in health and happiness that are associated with spending time outside in nature are well known and have been studied extensively by the scientific community. These benefits include; i) increased levels of happiness and self-esteem, ii) increased cognitive abilities, and iii) decreased stress response, blood pressure, pulse rates and cholesterol levels.

In a similar timeframe western society has changed its relationship with nature. The most obvious examples are that children’s play has moved from outdoors to indoors, the iconic backyard has shrunk, parents have become increasingly anxious about their childrens’ safety, working hours and stress levels have risen, and technology (especially screens) has encroached into almost all areas of life. We rely on our close affinity with nature in many ways, so it’s important to understand what can be done to ameliorate these trends.

The need and enjoyment of nature has been called ‘biophilia’, meaning ‘love of life or living systems’. The term was first used by the German-born American psychoanalyst Erich Fromm in 1964 to describe the psychological orientation of being attracted to all that is alive and vital. This term was further popularised by the American biologist, Edward O. Wilson, who introduced the hypothesis in his 1984 book *Biophilia*. The hypothesis suggests that there is an instinctive bond between human beings and other living systems. Wilson uses the term in the same sense when he suggests that biophilia describes; “the connections that human beings subconsciously seek with the rest of life”. He proposed the possibility that the close affiliations humans have with other life forms and nature as a whole are deeply rooted in our biology.

4.1 A DISCONNECT FROM NATURE

A significant global shift from agrarian to urban lifestyles is developing rapidly. Now more than half of the world’s population lives in urban environments, and the United Nations anticipates that this figure will grow to 66 per cent by 2050. These increasing urbanisation rates mean that people have less access to nature in their daily lives and most, on average, now spend over 90 per cent of their time immersed in man-made environments. This disconnect with nature and the outdoors has been shown to correspond with an increasing prevalence of obesity and mental health issues. A number of researchers have highlighted the major benefit and opportunity that can be realised by bringing the restorative qualities of natural outdoor environments into the indoor locations where we spend most of our time.

4.2 BIOPHILIC DESIGN

The incorporation of nature and its components into building design has been termed ‘biophilic design’. However, biophilic design is not a new practice. All over the world, and for centuries, people have used animal and plant motifs, incorporated gardens, ponds and atria into buildings and “brought the outside in” using plants and animals.

There are many examples of this, including Japanese timber-framed structures which show a high level of reverence for the trees and other materials used in their construction. More recently, many of Frank Lloyd Wright's projects included elements of biophilic design, from Samara, which incorporates a winded seed motif in the home's windows and elsewhere, to Fallingwater, one of the best-known examples showing how a building can be closely integrated with its environment.

The foundations of human psychology are predicated on our instinctive reactions to the natural world. Our brains are preconditioned by evolution to seek out places that provide refuge whilst also enabling us to look about and prospect, to consider what comes next. We are predisposed to explore and discover nature, and to respond to the weather, the seasons and the time of day.

Biophilic design is a synthesis of principles for designing the places where people live, work, heal and learn. It recognises that we need nature in a deep and fundamental fashion, but we have often designed our cities and suburbs in ways that both degrade the environment and separate people from it.

Biophilic design provides benefits through a number of proposed routes, including: i) stress reduction - lowering of blood pressure, heart rate, stress hormones and a sense of wellbeing; ii) improved cognitive performance - mental engagement, alertness, concentration, physiological and psychological responsiveness; and iii) emotion, mood and preference - positive attitude, happiness, tranquility, mental health, pleasure, comfort, safety and dopamine levels.

4.3 RESTORATION AND HUMAN STRESS

In order to improve occupant wellbeing in the built environment, important design decisions must be made which balance occupant needs and health impacts with other goals such as cost, environmental impacts and design aesthetics. To achieve these goals, it is important that designers understand human stress and the need for restoration, and are able to incorporate building design processes that bring those issues to the forefront in their work. Many restoration theories stem from the field of environmental psychology and have helped to lay the foundation for building design methodologies that emphasise occupant health, nature, and sustainability.

4.3.1 Restoration theories

Restoration has been defined as, "a process of renewal that replenishes a depleted social, psychological or physical resource". These resources have most often been depleted by an individual's effort to adapt to their environment. Early restoration theories focused on recovery from psychophysiological stress and attention restoration.

Psychophysiological stress recovery theory posits that natural environments, and even views of these environments from within a building, will aid recovery from both psychological and physical stress (for example, when recovering from surgery). Furthermore, attention restoration theory (ART) focuses on understanding how individuals replenish their ability to maintain attention on common tasks, such as those at the workplace that require a high level of attention to detail.

4.3.2 Restorative environmental design

A new design paradigm, highlighted by Stephen R Kellert in his 2008 book, *Biophilic design: the theory, science and practice of bringing buildings to life*, proposes a concept called restorative environmental design (RED), an approach that seeks to achieve both low environmental impact by lessening adverse impacts on the natural environment, and a biophilic design approach that fosters a higher level of contact between people and nature in the buildings they inhabit. This theory recognises that it is not sufficient to merely focus on the low environmental impact objectives of minimising harm to natural systems, but that it is also necessary to restore and enhance our positive relationship to nature in the built environment.

In principle, the three goals of restorative environmental design are to; i) reduce the environmental impacts of new buildings, ii) ensure buildings provide healthful benefits to their occupants, and iii) promote a stronger connection to nature.

4.3.3 Wood as an element of restorative environmental design

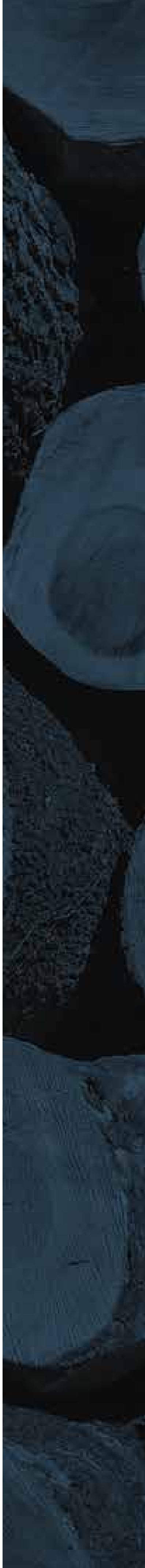
Wood is an ideal material to help provide restorative environmental design because it satisfies both of the requirements of the design paradigm; sustainability and a connection to nature. Furthermore, a growing body of research investigating psychophysiological responses to wood in the built environment supports the idea that the interior use of wood has positive health implications for occupants. Wood from healthy, well-managed forests is a renewable and abundant material that provides long-term carbon storage. It's therefore unsurprising that such a product, when used in the structure and interior design of buildings, provides a direct and unambiguous connection to nature.

4.4 WOOD AND BIOPHILIC DESIGN

When used well wood creates buildings that combine many of key elements of biophilic design, which complement the use of natural light and air flow, and views of green spaces. Wood can also be used to reflect the patterns and shapes seen in nature, known as biomorphism, and as a natural material on display in a building.

Kellert (2008) highlighted six biophilic design tenets, each of which could potentially be addressed using wood, as follows:

1. **Environmental features**; wood provides a direct link to nature, being a recognisable natural element
2. **Natural shapes and forms**; patterns in wood grain are naturally developed and wood can be used in forms representative of the material as a living organism
3. **Natural patterns and processes**; grain patterns, wood's colour spectrum, and the presence of knots evoke natural patterns and process
4. **Light and space**; wood has wide colour diversity and can be stained in a variety of colours without losing its familiarity as a natural product, and it can easily be deployed in products of various sizes to address space concerns
5. **Place-based relationships**; using locally sourced wood products can evoke a regional connection to nature, and historical and regional building methods, which utilised wood, may also be imitated
6. **Evolved human relationships with nature**; trees and wood have long been used as source for shelter, tools, transportation, and art



4.5 HEALTH BENEFITS OF WOOD

Wood provides a direct and unequivocal connection with nature; it is a natural material that is often used with minimal processing to provide both functional uses and aesthetic beauty. Used well the connection to nature provided by wood can extend into boosting our health and wellbeing.

Research on the health impact of natural materials, including wood, is a nascent but burgeoning area of study. The research typically examines the physiological response to varying quantities of materials, such as wood, compared with other materials, by measuring the impact upon various parameters associated with health, such as heart rate, blood pressure or cognitive performance.

The objective of much of the research is to explore how wood can be used to enhance the indoor environment using its inherent characteristics, be they visual, physical or tactile. We experience wood across the range of our senses and for many of us touching wood is not just for luck but also a response to the texture and warmth of the material.

4.6 PROVEN BENEFITS ON OUR BODY, OUR BRAIN AND THE AIR

A number of studies to examine the effects of wooden rooms and furnishings on human inhabitants have clearly demonstrated that the presence of wood can have positive physiological effects, lowering blood pressure and heart rate, providing improved thermal comfort and reduced stress responses when compared to other material types.

In addition, a number of studies have also examined the impact of wood (used architecturally) on our brain. The results of these studies indicate that the presence of wood has a positive impact on our psychology. The positive psychological outcomes of people interacting with wooden products could have significant economic impacts, including reducing the risk of dementia and shortening hospital stays through reduced recovery times.

Wood products within a room have been shown to improve indoor air quality by moderating humidity. This effect occurs due to wood absorbing or releasing moisture in order to maintain equilibrium with the surrounding air. The ability of wood to moderate humidity is a particularly important effect in workplaces; worker productivity has been demonstrated to be reduced by an average of 12 per cent in offices where staff are dissatisfied with the quality of the air.

4.7 WOOD IS ASSOCIATED WITH AN ENHANCED FEELING OF WELLBEING

Hundreds of studies from around the world have concluded that natural elements like sunlight, views of nature, vegetation, indoor air quality, and the use of natural materials have a positive impact on our wellbeing. For example, studies have demonstrated that simply having a view of nature from a window can have significant positive effects, such as shorter postoperative hospital stays, induced feelings of relaxation in patients at rehabilitation centres, and improved comfort levels of employees in offices. The presence of indoor plants has also been shown to have benefits, such as improved cognitive functioning in office environments, increased tolerance of pain in hospital, and lowered blood pressure and heart rate.

In addition, a number of studies have identified that the presence of wood indoors is associated with an enhanced feeling of wellbeing, such as: i) in aged care homes plants and natural materials (including wood) were associated with a subjective improvement in wellbeing; ii) hospital rooms with wooden furniture were identified as more appealing and rated higher by their staff, and iii) when employees at a Norwegian hospital were asked to rate patients' rooms with different degrees of wood, they indicated that patient rooms with an intermediate level of wood were the most preferred.

4.8 OUR PHYSIOLOGICAL RESPONSES ARE CONTROLLED BY THE SYMPATHETIC NERVOUS SYSTEM

The responses described above are specifically controlled by the sympathetic nervous system (SNS). SNS activation occurs when the body prepares itself for stress, increasing blood pressure and heart rate, whilst inhibiting digestion, recovery and the immune system in order to deal with any immediate threats it perceives. Studies have clearly demonstrated that long-term exposure to (man-made) environments that induce stress can trigger serious health consequences, including obesity, type 2 diabetes and related cardiometabolic complication.

4.9 NOT JUST A WHIM, WOOD IS DEFINITELY GOOD FOR OUR HEALTH

The foregoing discourse has highlighted that, in our homes and offices, schools and hospitals, the indoor environment we inhabit will have a significant impact on us. In workplaces healthier environments can reduce sick leave and increase productivity, which has a direct impact on profitability. Similarly, in addition to enhancing relationships with nature, healthy school environments can help to improve student performance and learning.

The use of wood in the interior of a building has clear physiological and psychological benefits that mimic the effect of spending time outside in nature. The feelings of natural warmth and comfort that wood elicits in people has the effect of lowering blood pressure and heart rates, reducing stress and anxiety, increasing positive social interactions and improving corporate image.

Wood is one of the oldest and most versatile building materials used by humanity, but now more than ever it has a large part to play in the design and construction of healthy buildings for us to live, work, learn and recover in.

5. BENEFITS OF WOOD IN A CIRCULAR ECONOMY

5.1 WHAT IS THE CIRCULAR ECONOMY?

A circular economy is a system that allows the added value in products to be kept for as long as possible and in which waste is eliminated. When a product has reached the end of its life, the resource is kept within the economy, so that the product or component is used multiple times and, consequently, provides ongoing value. This is predicated on the circular (closed) flow of materials and the use of raw materials and energy through multiple phases.

The concept of a circular economy has its roots in several different schools of thought and theories that challenge the prevailing economic system based on overconsumption of natural resources. In recent years the circular economy has received increasing worldwide attention due to the growing recognition that the security of supply of resources and resource efficiency are crucial for the prosperity of economies and businesses. The concept has been taken up by a number of governments and businesses around the world who collectively consider the circular economy as a solution for harmonising the apparently conflicting objectives of economic growth and environmental sustainability.

At the same time, changing the prevailing linear economic model that has remained dominant since the onset of the Industrial Revolution is not straightforward and will entail a transformation of our current production and consumption patterns, which are not restricted to specific sectors or materials. Such a major transformation would, in turn, entail significant impacts for the economy, the environment and the society.

Despite its current status as one of manufacturing's pre-eminent axioms, the concept of the circular economy has been around since at least the 1970s. It has been proposed as a solution to resource security and scarcity issues, both locally and internationally, and as a way to reduce the environmental impacts of production and consumption, through methods including designing out waste, disruptive innovation, new leasing models and the use of renewable materials (like timber).

Growing international research and evidence shows numerous benefits over the traditional linear economy. These include; i) long-term cost savings, ii) increased local job opportunities, iii) encouragement of technical innovation, iv) reducing the amount of waste produced, and v) reversing our impacts on climate change. When a product's component materials are reused rather than entering landfill, not only is that material no longer waste but also new raw materials are not required to be extracted (or grown).

Adopting a circular economy system has a strong economic case and it is manufacturers that are most likely to reap the benefits quickest given their heavy reliance on raw materials. In short, a move to a circular economy can deliver a more competitive economy, and further opportunities for growth. Undoubtedly one of the key industries that can benefit maximally from the development of new eco-technologies and circular economy is the building and construction industry.

5.2 REDUCING EMBODIED CARBON

Choosing materials that have a high recycled content generally results in a building that has a lower embodied carbon footprint. Another effective way of reducing the embodied carbon in a building is to specify reused materials, as these will usually have only a small energy and carbon impact (mainly from transportation) after their first life. Furthermore, reused materials have been shown to have significantly less environmental impact when compared with recycled materials. For example, a recycled steel section has been estimated to have approximately 25 times the environmental impact of a reused steel section, and hence by reusing steel a 96 per cent environmental saving can be achieved when compared with using virgin steel.

For additional information, please refer to Design Guide Chapter 2.1: Sustainability – Timber, Carbon and the Environment.

5.3 WHY IS WOOD THE MATERIAL OF CHOICE FOR THE CIRCULAR ECONOMY?

Needing little more than sunlight and rainfall to grow, the production of timber requires significantly less energy than other, more carbon-intensive building materials such as concrete and steel. In many instances timber is capable of replacing these materials in a variety of building applications, and can also help to increase the impact and resulting benefits of the circular economy in the construction sector.

Wood is both valuable and versatile, and can be employed in a wide range of forms, including construction materials, furniture and packaging. The economic return of the recycling and reuse of wood is surprisingly efficient, starting from the collection phase to the transportation to wood recycling facilities.

5.4 DURABLE AND INNOVATIVE

In a fast-evolving world, versatility and durability are high priorities if a product or material is to become part of the circular economy. Wood is a highly durable building material. Modern treatments mean that wood can resist biological degradation even longer, as well as locking in biogenic carbon. The long-lasting nature of timber products also makes them excellent value for money. For example properly maintained timber windows have in some cases lasted well over 100 years; the oldest surviving examples of wooden sash windows were installed in the 17th Century at Ham House in the United Kingdom.

As an example a life cycle assessment report by the Wood Window Alliance (UK) showed that over a 60 year design life timber windows offer the lowest cost alternative for mild climates, while aluminium clad and modified timber windows offer lower whole life costs for moderate and severe climates. This compares to PVC-U windows which were shown to have the highest whole of life costs over 60 years in all scenarios. It has been shown that the timber-based frames last longer, are better value and have significantly lower environmental impacts than comparable PVC-U frames.

5.5 FACTORS INFLUENCING THE REUSABILITY OF BUILDING MATERIALS

The reusability of recoverable building materials is affected by environmental, design and construction as well as operation and management factors. The specification of reusable building materials during the design and construction phase is a major factor that determines the level of reusability of recoverable materials at the end-of-life of a building. Other factors that influence the reusability of recoverable materials include the use of screws or bolted joints instead of nails and glueing, hence the ability to more easily deconstruct buildings, and the wider use of prefabricated assemblies.

5.6 IMPACT OF IMPURITIES IN WOOD

Impurities in wood are typically material or chemical contaminants, and generally include metals, plastics, textiles, glass, adhesives, paints, waxes, preservatives, and fire retardant treatments. From these sources substances such as metals and persistent organic pollutants can originate and accumulate in the wood.

For wood to be used in a circular way, evaluating the presence of chemicals in waste products is critical as they may re-enter the life cycle of the new recycled product along with the targeted material (risk-cycling). Accordingly, achieving a clean and safe circular economy relies on the development and implementation of appropriate methods to monitor levels of impurities in the waste, identify contaminated waste flows and separate them before recycling.

5.7 WOOD'S POTENTIAL ROLE IN PLASTIC REDUCTION

Wood biomass has the potential to provide the raw materials required to replace plastic; by-products of the wood industry can create new plastics which can then be recycled or reused at the end of their life, unlike most plastics. Adopting some of the techniques and research around using wood for bio-plastic production could potentially benefit the circular economy and create a significant positive impact on the environment.

As an example lignin is one of the wood compounds which can be used to create plastic parts. Research has shown that it can be processed through extrusion machinery to produce plastics for packaging or building materials. It is also possible to use the by-products of wood bark extraction to produce a duroplastic bio adhesive; a very hard and resistant adhesive that could be used to replace common adhesives for the production of wood-based panels.

5.8 ENERGY FROM WASTE

Energy from waste, thermal treatment coupled with energy recovery, could also play a central part in the development of a circular economy. It is a key method for taking the residual element of wood waste stream and converting it via incineration into a form of energy, either electricity or heat. Energy from waste also helps to provide low cost, sustainable and secure energy.

5.9 WOOD FOR HEATING

A rapidly-expanding trend in home heating involves the use of wood-pellet burners. Wood pellets are made from compressed sawdust and shavings, and provide a number of benefits including continuous and adjustable heat, reduced maintenance and reduced air pollution.

There is currently a pilot programme in New Zealand to replace coal-using boilers in schools with pellets. The program could potentially be extended to hospitals and hotels, and to industries such as dairy factories, cement works, meat works, and food processing plants.

Importantly biofuels are deemed to be carbon-neutral; their emissions are viewed as recycled atmospheric carbon rather than new additions. Wood has very little ash (about 1 per cent) but, unlike ash from coal, this is a useful fertiliser. There is very little smoke from a good quality wood-burner or pellet-burner, and emissions from wood, unlike those from coal, contain almost no sulphur.

5.10 WOOD FOR LIQUID FUELS

Wood can either be used to generate electricity or it can be converted to liquid fuels. Research has shown that by using wood-based biofuels New Zealand could be self-sufficient without harming the environment or adversely affecting food supplies.

The Crown Research Institute, Scion, is currently exploring ethanol production from wood and estimates that a harvest of only 125,000 hectares per year would meet all of New Zealand's requirements for both heat and transport fuels. Assuming a 30-year rotation, this implies a doubling of the existing forest area. In addition, technologies for gasification and pyrolysis, and techniques to dissolve wood under high temperatures and pressures are also being investigated.

5.11 WHAT TO EXPECT FROM THE FUTURE?

Employing materials that are highly recyclable and that can be maintained to prolong their life implies a change in perspective in both the (building) design process and business strategies. Shifting from linear economy to circular economy thinking clearly requires innovative production technologies, but it also creates room for new, profitable business models.

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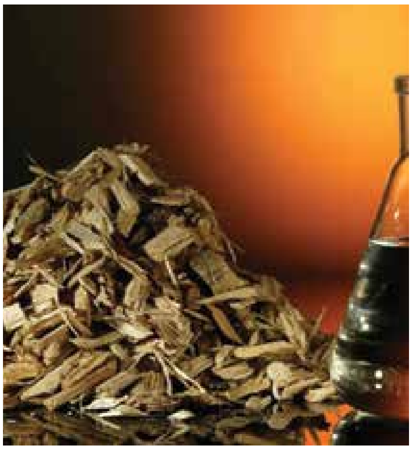

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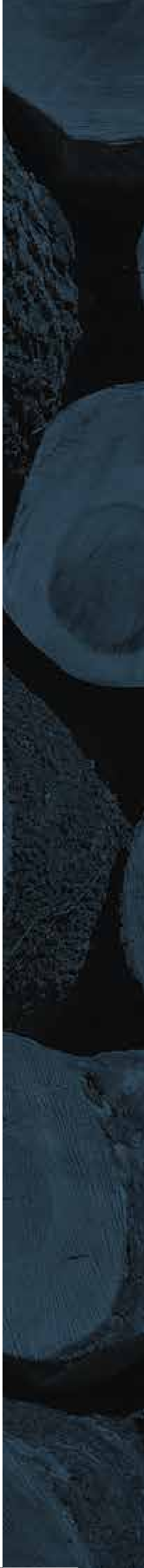

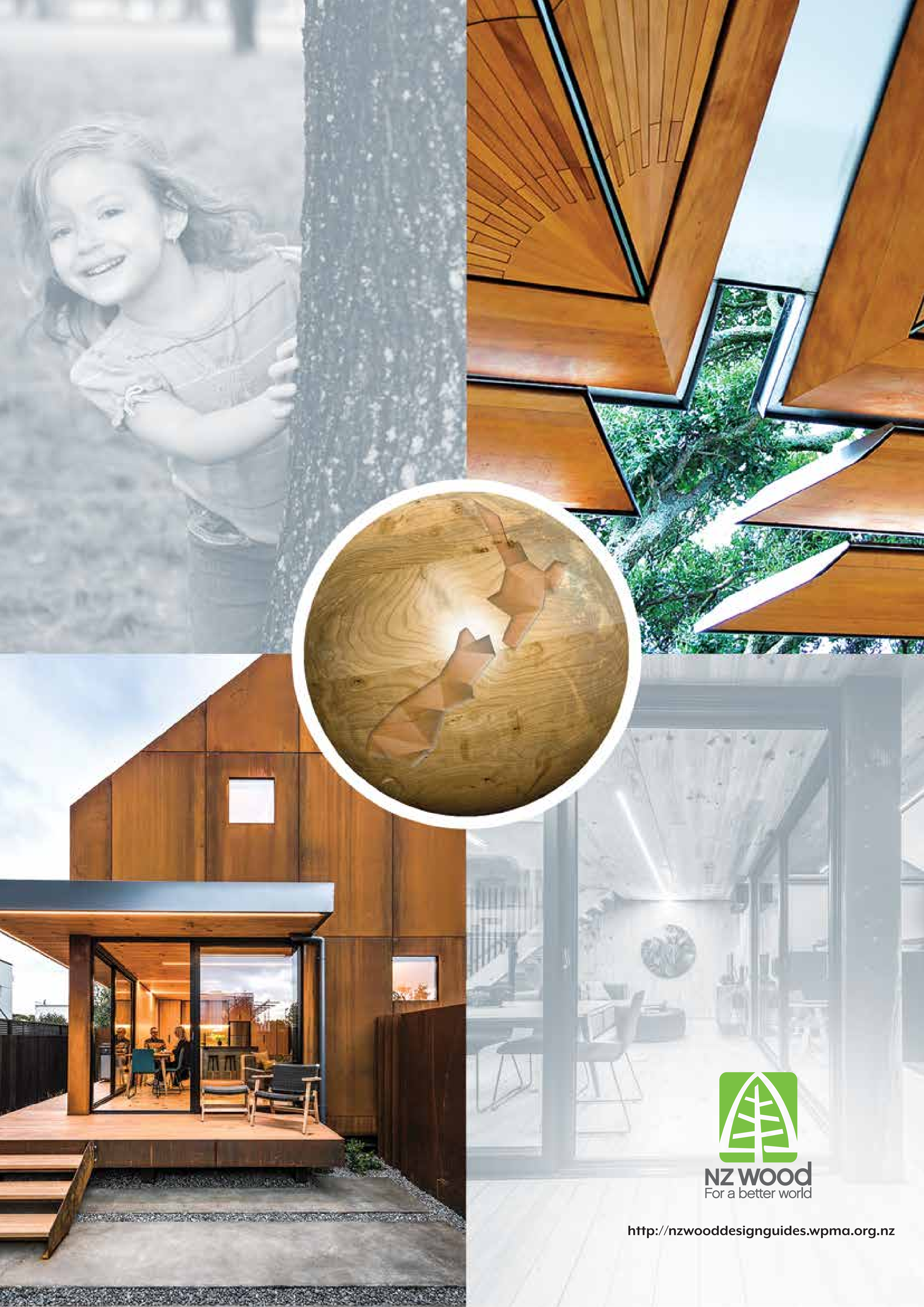

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