

# Wood

## Nature Inspired Design

An update of the Wood – Housing, Health, Humanity Report

**MAKE IT** WOOD

Do your world some good

**PLANET ARK**



Figure 1. Wood and nature connected design.

# Contents

About This Report	3	Cashing in on Nature Connected Design	20
Acknowledgements	3	Be Certain it's Certified	21
Executive Summary	4	What About Fire Safety?	22
Wood – Nature Inspired Design	5	Design to Last	23
Why Wood?	5	Showcasing Wood	24
Our Need for Nature	6	Dandenong Mental Health Centre	24
Love of Life and Nature	7	Marist College Bendigo Montagne Centre	25
Bringing Nature into the Built Environment	8	Melbourne School of Design	26
Restorative Environments	9	The Village Centre, National Arboretum, Canberra	27
Wood and Nature Connected Design	10	Tempe House, Tempe, NSW	28
Biomorphic Forms – Shapes of Nature	10	The Library at the Dock, Victoria Harbour, Melbourne	29
Health Benefits of Wood	12	Conclusion	30
Wood – A Raft of Benefits	12	Planet Ark Nature Related Research	31
Benefits on the Body	13	References	32
Benefits on the Brain	15	Index of Photographs	33
Benefits on the Air	16		
Visual Appeal, Natural Look	17		
Rating Nature Connected Design	19		

# About This Report

This report is an update and extension of the *Wood – Housing, Health, Humanity* released by Planet Ark to coincide with World Wood Day 2015. The aim of the original report was to examine current literature and empirical studies assessing the benefits of using wood in an indoor environment. That report also presented the results of a survey commissioned by Planet Ark and conducted by research consultancy Pollinate in September of the previous year. The survey focused on the current opinions and attitudes of Australians towards wood along with their exposure to it at home, work and school (1003 Australians aged 14-64 years old and nationally representative in terms of age, gender and location were surveyed online).

This new report *Wood – Nature Inspired Design* builds on that original work and introduces the concept of biophilia – an affinity with nature or the love of all things natural – with a focus on the use of wood in biophilic, or nature connected design. The report looks at published research from around the world showing the health and wellbeing benefits of exposure to this most ancient and modern material.

## Acknowledgements

Planet Ark's Make It Wood program has developed this report with support from Forest and Wood Products Australia's *Wood Solutions* and *Wood. Naturally Better* programs. The research and report writing was undertaken by Planet Ark staff member Dr Sean O'Malley, with advice, research and editing assistance by Brad Gray and David Rowlinson. The report includes elements from the 2015 review written by Dr Amanda Cameron. Attitudinal research was managed by Bernard Visperas from Pollinate with graphic design by Slade Smith. Planet Ark is grateful to a number of designers and photographers whose work has been included in this report, as detailed in the tables on page 33.

**Figure 2. Humans gain health and wellbeing benefits from exposure to this most ancient and modern material.**



# Executive Summary

Over recent years there has been an increasing recognition of the benefits that humans gain from contact with trees and nature. Modern society has changed its relationship with nature. In the space of a single generation children's play has moved from outdoors to indoors, the iconic backyard has shrunk, parents have become increasingly anxious about children's safety, working hours and stress levels have risen and technology (especially screens) has encroached into almost all areas of life.

The health and happiness benefits associated with spending time outside in nature are well known and have been studied extensively by the scientific community and reported on by Planet Ark. This love of time in nature has been termed biophilia<sup>1,2</sup> and explains our innate need to connect with the natural world. This relationship can be extended into the built environment where we work, rest and play. This report outlines the importance of connecting buildings with the natural world and how with 'Nature Connected Design' (biophilic design<sup>3</sup>) and using wood we can bring nature indoors and provide a healthier, happier environment.

Some of the elements of nature connected design are discussed and how these can be realised through the use of thoughtful construction and the use of wood. Nature connected design is not a prescriptive list;

rather it is a series of principles that can be blended into variable palettes to reflect the benefits of time spent in nature.

Additionally, this report updates our previous review of studies analysing the health and wellbeing benefits of wooden interiors in homes, businesses, places of learning and places for healing, along with the results of an independent survey identifying the attitudes and opinions of Australians on wood.

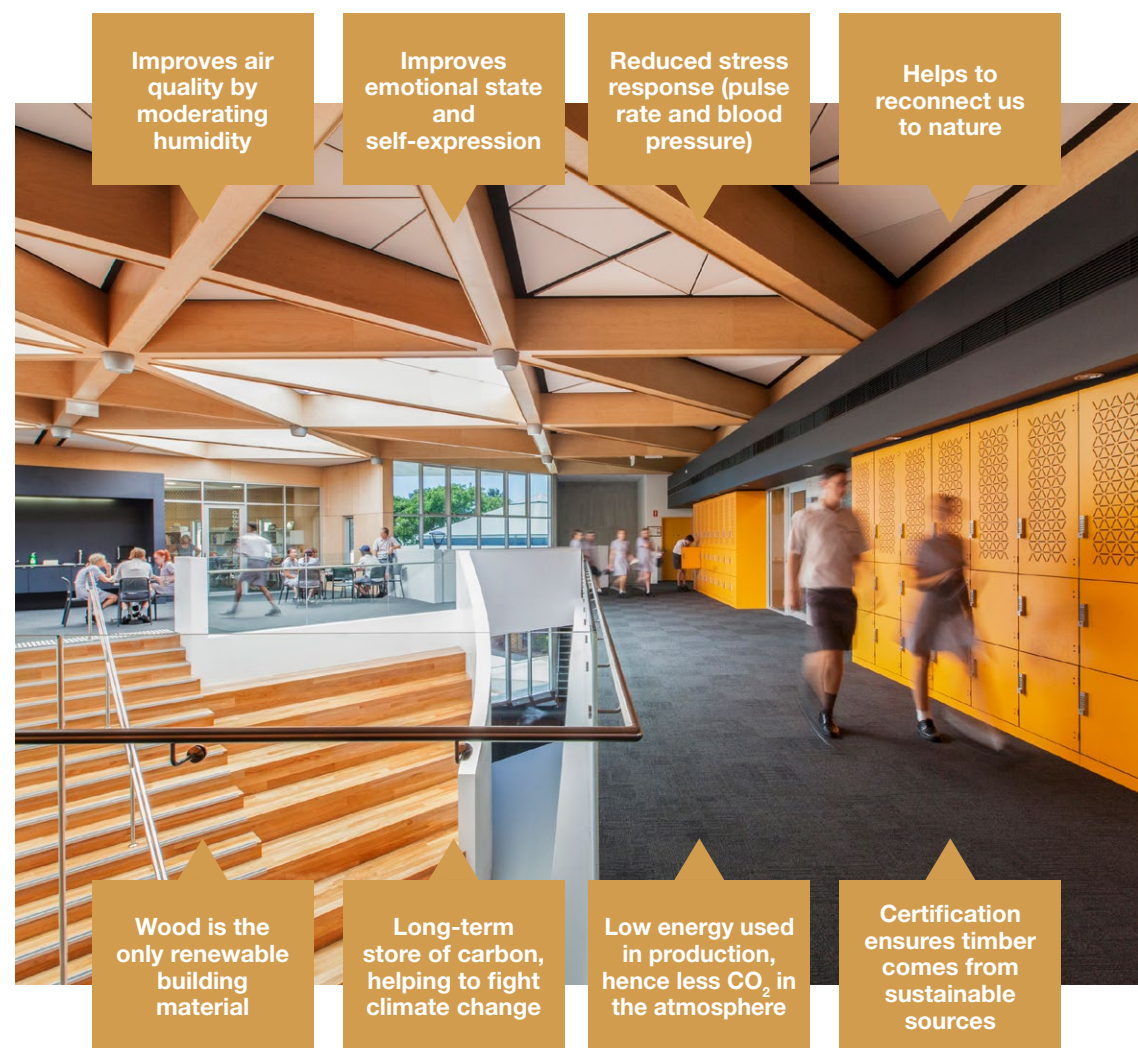
Multiple physiological, psychological and environmental benefits have been identified for wooden interiors:

- Improvements to a person's emotional state and level of self-expression
- Reduced blood pressure, heart rate and stress levels
- Improved air quality through humidity moderation
- Its use as a long-term store of carbon, helping to fight climate change

Surveyed Australians appear to be innately drawn towards wood. The results indicate that wood elicits feelings of warmth, comfort and relaxation and creates a link to nature. However, Australians, appear to still be confused about wood certification.

Promoting nature connected design and the benefits gained from using timber to the general public, home owners, designers and architects is therefore of significant importance.

## The Benefits of Wood and Nature Connected Design



**Figure 3. The benefits of wood and nature connected design.**



Figure 4. Wood is being increasingly used for its positive impacts on health and wellbeing.

# Wood – Nature Inspired Design

## Why Wood?

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.

Responsibly sourced, certified timber is the only major building material that helps to tackle climate change. As trees grow they absorb carbon dioxide from the atmosphere and, through photosynthesis, convert this into sugars that form the compounds that comprise wood. Approximately 50 per cent of the dry weight of wood is carbon, which remains locked in the wood for the life of the product. Timber is also the only renewable building material currently available.

The energy consumed in the production of timber, called embodied energy, is much lower than other building materials, which means that by using more wood in the built environment as a replacement for carbon-intensive materials such as aluminium, steel or concrete, it is possible to significantly reduce the carbon emissions in the construction of homes, schools, hospitals, offices and public buildings<sup>4,5</sup>

Although wood has ancient roots and has been used in every culture in the world since before the Stone Age it is experiencing a revival in use. 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 being increasingly used for its positive impacts on health, wellbeing and productivity, producing similar effects to those created by spending time outside in nature.

## Our Need for Nature

As far back as 1995 Planet Ark knew the value of spending time in nature and organised the first National Tree Day. Over the intervening 21 years nearly 4 million people have planted over 23 million trees right across Australia. The event began primarily focusing on the environmental benefits of plants and trees; producing oxygen, filtering the air, removing carbon from the atmosphere, stabilising soil, providing essential habitat for native animals and beautifying neighbourhoods.

Over recent years there has been an increasing recognition of the benefits that humans gain from contact with trees and nature. Modern society has changed its relationship with nature. In the space of a single generation children's play moved from outdoors to indoors, the iconic backyard shrunk, parents became increasingly anxious about their children's safety, working hours and stress levels rose and technology (especially screens) encroached into almost all areas of life.

The health and happiness benefits associated with spending time outside in nature are well known and have been studied extensively by the scientific community and reported on by Planet Ark<sup>6</sup>.

These known benefits include:

- Increased levels of happiness and self-esteem<sup>7,8</sup>
- Increased cognitive abilities<sup>9,10</sup>
- Decreased stress response, blood pressure, pulse rates and cholesterol levels<sup>11,12</sup>



Figure 5. Wood creates increased levels of happiness and self esteem.



## Love of Life and Nature

The need and enjoyment of nature has been called 'biophilia', meaning 'love of life or living systems'. The term was first used by Erich Fromm<sup>1</sup>, back in 1964, to describe the psychological orientation of being attracted to all that is alive and vital. This term was popularised by the scientist, Edward O. Wilson<sup>13</sup> who introduced the hypothesis in his book, *Biophilia* (1984)<sup>2</sup>. 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 deep affiliations humans have with other life forms and nature as a whole are rooted in our biology.

Increasing urbanisation rates mean that people have less access to nature in their daily lives and Australians on average

now spend over 90 per cent of their time indoors<sup>92</sup>. This disconnect with nature and the outdoors corresponds with reports of increasing levels of obesity<sup>14</sup> and nearly half of Australians experiencing a mental health condition within their lifetime<sup>15</sup>.

As it is not always possible to increase our time spent outside, particularly in areas like workplaces, schools and hospitals, understanding how to incorporate the physiological and psychological benefits of nature into our indoor environments is an increasingly important area of research.

Studies have demonstrated that simply having a view of nature from a window can have significant positive effects, such as shorter postoperative hospital stays<sup>16</sup>, induced feelings of relaxation in patients at rehabilitation centres<sup>17</sup>, and improved comfort levels of employees in offices<sup>18</sup>. Not surprisingly the presence of indoor plants has also been shown to have benefits, such as improved cognitive functioning in office environments<sup>19</sup>, increased tolerance of pain in hospital<sup>20</sup> and lowered blood pressure and heart rate<sup>21</sup>.

**Understanding how to incorporate the physiological and psychological benefits of nature into indoor environments is an increasingly important area of research.**

**Figure 6. Nature connected design reflects the link between the natural and built environments.**

The incorporation of nature and its components into building design has been termed 'biophilic design'. To aid the community and decision makers to understand the concepts that underpin biophilia and biophilic design we have used the more descriptive term 'nature connected design'. It reflects the link between the natural and built environments.

## Bringing Nature into the Built Environment

Nature connected design is a response to the need to bring nature into the built environment. It combines the design theory, science, art and practice of bringing buildings to life and aims to provide the connection with nature in the environments where we live and work in every day<sup>3</sup>.

Nature connected 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.

There is now a large body of work on urban planning and green cities, both globally and across Australia, which demonstrates a significant and beneficial role for including nature and green infrastructure<sup>22</sup>. The inclusion of trees, green roofs and vertical gardens are increasingly seen as important for healthy and happy cities. Good design, with the inclusion of nature into the urban environment, now termed biophilic urbanism, is increasingly being shown to have demonstrable benefits for not only our physical environment<sup>23</sup> but also our health<sup>24</sup>.

A recent study highlighted the inclusion of green areas, particularly trees, helps reduce particulate matter and the high temperatures associated with urban areas, both of which can have significant negative impacts

on human health<sup>25</sup>. In Australia there is a significant movement to increase the amount of green space and trees in urban areas, with projects such as the 2020 Vision which seeks to increase the amount of green space in our urban areas by 20 per cent by 2020<sup>26,27</sup>. Other projects<sup>28</sup> are focused on greening rooftop areas to provide access to green spaces for urban workers and residents.

Not only does the inclusion of nature in the urban environment provide significant benefits for our mental health and happiness, it is now being closely studied for the economic benefits provided to urban areas<sup>29,30</sup>.

Creating a nature connected urban environment is not just about the external surrounds; nature connected design also integrates natural elements into the living and working environments. Nature connected design seeks to establish a new framework to bring the connection with nature into the built environment. Good design creates a habitat where we, the human organism, can derive the health and fitness benefits associated with time in nature.



**Figure 7. Lendlease's breathing wall – bringing nature into the built environment.**



The practice of nature connected design has been developed into a series of principles, experiences and design attributes<sup>31</sup>, which are required as fundamental conditions for its effective implementation<sup>32</sup>. Nature connected design requires a repeated and sustainable connection with nature, with a focus on the elements that are linked to our health, fitness and wellbeing. This includes creating emotional links with the environment that are about positive interactions that increase our relationship and care for the human and natural communities. Architecture is used to reinforce and connect us in this relationship.

Nature connected design includes a multitude of elements that stimulate the human senses, including sight, touch and even olfactory. Natural elements are used to enhance the built environment. Plants, natural views, light, water, airflow, and temperature are all part of the available repertoire. Nature connected design is not a prescriptive list; rather it is a series of principles that can be blended into variable palettes. Cultures and societies across the planet use different forms and designs that reflect local conditions and histories. Research has identified six dimensions and seventy elements of nature connected design<sup>3</sup>.

**Nature connected design is not a prescriptive list; rather it is a series of principles that can be blended into variable palettes.**

## Restorative Environments

Ideas as to why time in nature and nature connected design positively impact people include the Attention Restoration Theory<sup>33</sup> and Stress Recovery Theory<sup>34</sup>. These theories suggest that some environments are inherently stressful, some are not and others can actively help people recover from stress and mental fatigue. Built environments that evoke positive moods have properties that draw people's attention without being stressful or demanding and can help people recover more quickly and fully from mental fatigue and stress are known as restorative environments<sup>35,36</sup>. A restorative environment will be observed as a healing, healthy and therapeutic environment, which contributes to people's physical and mental wellbeing.

Nature connected design provides benefits through a number of proposed routes<sup>37</sup>, including:

- Stress reduction - lowering of blood pressure, heart rate, stress hormones and a sense of wellbeing
- Cognitive performance - improved mental engagement, alertness, concentration, physiological and psychological responsiveness
- Emotion, mood and preference - positive attitude, happiness, tranquillity, mental health, pleasure, comfort, safety and dopamine levels

A 2015<sup>38</sup> study explored the relationship between office workers' psychological wellbeing, work environments and employee

expectations. For many workers, the design of an office was important in their decision to work at a company. The presence of plants and other natural elements were also identified as important. The report also showed national and cultural differences were apparent, with Australians identifying the use of wood in office design and furnishings as contributing to greater productivity. The authors identified that there is a high cost to Australian business from a loss in productivity from the impact of stress on the health of workers (Medibank<sup>39,40</sup>). Considering the positive benefits posed by nature connected

design, there is a clear potential to improve worker health.

Australians identified the following natural elements in office settings as being beneficial:

- Window views of trees, both natural and purposely planted, was associated with greater levels of happiness
- Views of trees through windows, and the use of the colour green, was linked to greater creativity
- Wooden office fixtures and fittings, as well as the use of blue, was associated with greater productivity

**Figure 8. Restorative environments help people to recover more quickly.**



## Wood and Nature Connected Design

Timber is a natural, organic material, and it has 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, such as cross-laminated timber (CLT), glued laminated timber (glulam) and laminated veneer lumber (LVL).

When used well wood creates buildings that combine many of the key elements of nature connected design, including natural light, air flow and views of green spaces.

Wood can also be used to reflect the patterns and shapes seen in nature, also known as biomorphism<sup>37</sup>, and as a natural material on display in the building. Both nature connected elements are discussed in the following sections and how they are linked through use or research to positive health and wellbeing.



**Figure 9. Engineered timber has become a primary structural component.**

## Biomorphic Forms – Shapes of Nature

Biomorphism describes the modelling of design elements on naturally occurring patterns or shapes reminiscent of nature and living organisms. Taken to its extreme it attempts to employ naturally occurring shapes onto functional devices. The development of modern engineered timber technologies has allowed the arrangement of timber into ever more complex forms. Supporting structures can now resemble the arrangement of trees and their branches, as exhibited in the Village Centre, National Arboretum in Canberra<sup>41,42</sup> and the Credit Valley Hospital with its tree filled atrium to inspire patients. The idea for the grove of timber trees flourishing in the atrium of Credit Valley Hospital's Carlo Fidani Peel Regional Cancer Centre, in Mississauga, Ontario, grew out of visits by architect Tye Farrow to 30 cancer centres in North America and Europe, where patients told him they wanted fewer hotel-like amenities and "more reasons to feel hopeful."<sup>43</sup>

**The design for Credit Valley hospital was inspired by cancer patients saying they wanted fewer hotel-like amenities and "more reasons to feel hopeful".**



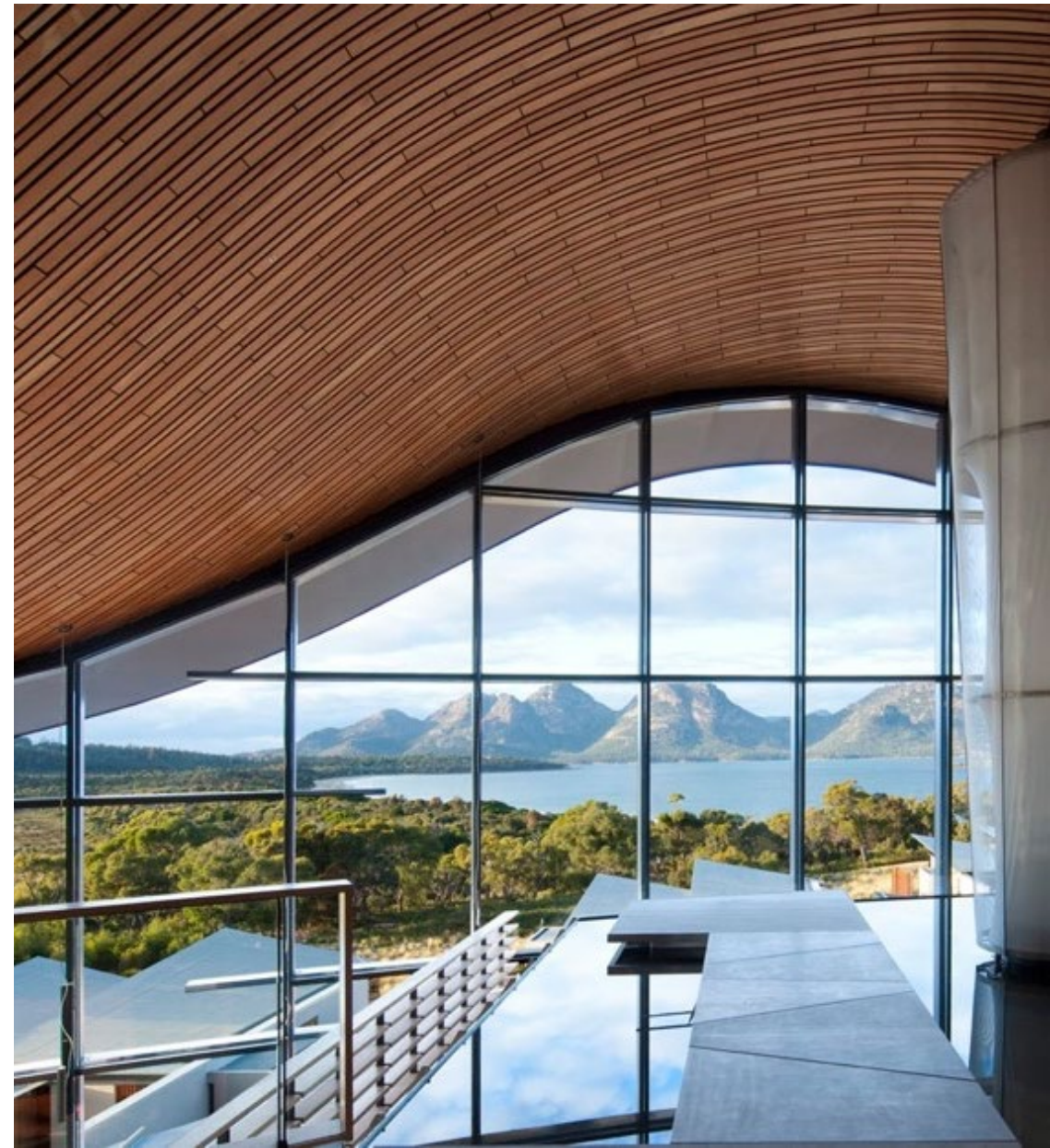
**Figure 10. Credit Valley Hospital's Indoor Forest.**



“We decided to create an environment that appeared to be alive and growing,” says Farrow, a senior partner at Farrow Partnership Architects. He made a few sketches and models of the 11,500-square-foot space before creating a triangular floor plan centered on four sprawling columns comprising Douglas fir glulam members.

Biomorphic timber forms now appear in other public situations, for example the Metropol Parasol in Seville. The structure consists of six parasols in the form of giant mushrooms, whose design is inspired by the vaults of the Cathedral of Seville and the Ficus trees in the nearby Plaza de Cristo de Burgos. Similarly, the spectacular Saffire Resort at Freycinet, Tasmania evokes a connection to the sea through references to waves, sea creatures, sand dunes and a flowing, organic form.

**Figure 11.**  
Biomorphic timber  
forms in the Metropol  
Parasol in Seville.



**Figure 12.** Saffire  
Resort evokes a  
connection to the sea  
through a flowing,  
organic form.



# Health Benefits of Wood

## Wood – A Raft of Benefits

Wood provides a material 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 nature connection provided by wood can extend into boosting our health and wellbeing.

Research on the health impact of natural materials, including wood, is a growing but still a limited area of study. The research typically examines the physiological response to variable quantities of materials such as wood compared with other materials and the impact upon various parameters associated with health, such as blood pressure or cognitive performance.

The term neuro-architecture has also been coined to define the process of informing design by correlating specific measures of the built environment with quantified measures of the brain's and body's responses (neural, physiological and psychological responses), as well as sociological, behavioural and economic outcomes<sup>44</sup>.

The objective of much of the research is to explore how wood can be used to enhance the indoor environment using its characteristics, be they visual, physical or even 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<sup>45</sup>.

Two significant reviews of the role of wood on health have been performed. Nousiainen 2013<sup>46</sup> examined the role of wood in creating a restorative environment, and Augustin and Fell 2015<sup>47</sup> have provided a more recent review on this topic.

**Figure 13. Wood provides a material connection with nature.**

## Benefits on the Body

A number of studies have examined the impact of wood upon our body. The results of these studies indicate that the presence of wood has an impact on our physiology.

- A Japanese study compared the initial physiological response of 14 people sitting in rooms with either wooden or steel wall panelling. The pulse and heart rate of each subject was measured every second for 20 seconds whilst facing the panelled wall covered by a curtain, followed by 90 seconds with the curtain removed and the wooden or steel panel visible. The study found that exposure to wooden panels significantly decreased the blood pressure of subjects, whilst exposure to steel panels significantly increased it<sup>48</sup>.
- An Austrian study examined the heart rates of 30 people who slept in a Stone Pine bed for 3 weeks and compared it to their heart rates when sleeping in a wood imitation bed for 3 weeks. Sleeping in a stone pine bed reduced heart rates by 3,500 beats per day compared to when subjects were sleeping in a wood imitation bed<sup>49</sup>.
- A year-long study examined 36 high school students aged 13-15 years who were taught in either a classroom furnished with floors, ceilings, cupboards and wall panels made of solid wood, or a classroom equipped with a linoleum floor, plasterboard walls and chipboard cupboards. The results showed significant differences between the two groups, with students taught in the

wooden classrooms having decreased heart rates and decreased perception of stress from interactions with teachers. In contrast, students taught in the control classroom had increased heart rates and had greater stress responses<sup>50</sup>.

- Studies continue on examining the impact of wood to reduce stress in schools. A movement called 'Schule Ohne Stress', or 'Schools Without Stress', is examining the impact of wood on the health of pupils.
- A 2008 Japanese study<sup>51</sup> examined the benefit of adding wood panels and Japanese paper to the walls of a hospital isolation room. The results demonstrated a reduced stress level (measured by cortisol levels) experienced by people in the space compared to people who spent time in the room when it had its original concrete walls. The authors suggested the redecoration improved the thermal comfort of the room contributing to maintaining a preferable core temperature.
- A 2010<sup>52</sup> study of responses of 119 students in wood and non-wood offices before, during and after assignment to a stressful task. Test results showed that skin measurements indicated lower stress from subjects in the wood office compared to the non-wood office. The author concluded that the study provided evidence that wood produces stress-reducing effects similar to the effect of exposure to nature in the field of environmental psychology, and that this stress reduction property had a role as a part of the evidence-based and nature connected designs of hospitals, offices, schools, and other built environments.

- A 2005 study<sup>48</sup> looked at the psychological and physiological responses of viewing either a wooden or a white steel wall. Blood pressure dropped in those subjects with a preference for wood, whereas no change was observed in those that disliked the panels. Viewing the steel panels was said to provide a closed impression and a sense of depression, resulting in a rise in blood pressure in those subjects that disliked white steel. This result indicates that differing materials can have variable responses dependent on an individual's preferences. It is important to note that not all individuals will show the same response and have the same preferences.

These studies examining the effects of wooden rooms and furnishings clearly

demonstrate 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.

**Skin measurements indicated lower stress from subjects in the wood office compared to the non-wood office.**

**Figure 14. A home incorporating wooden structures and furnishings.**



These physiological responses 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. Long term exposure to environments that induce stress can trigger serious health consequences, including obesity, type 2 diabetes and related cardiometabolic complications<sup>53</sup>

Studies also suggest that exposure to stress and stress hormones during childhood and adolescence increases the sensitivity of individuals to the onset of stress-related mental disorders later in life<sup>54</sup>, the timing of puberty and body-composition<sup>55</sup>. Decreasing the stress of school (one of the most stressful activities in childhood<sup>56</sup>) by incorporating natural wood into the classroom can therefore have significant and long lasting positive effects.

**Long-term exposure to environments that induce stress can trigger serious health consequences.**

**Figure 15. School students have lower heart rates and decreased perception of stress.**





**Figure 16. The use of wooden products increases social interactions among elderly people.**

## Benefits on the Brain

In addition to the research highlighted above, a number of studies have also examined the impact of wood upon our brain. Again, the results of these studies indicate that the presence of wood has a positive impact on our physiology.

- The behaviours and health status of 44 elderly Japanese residents using wooden tables, chairs and tableware at a care home was examined and compared to those using plastic products. The results indicated that the use of wooden products increased the number of interactions between individuals (i.e. more talkative and more willing to engage with one another), improved emotional state and expanded self-expression in a positive way<sup>67</sup>.
- A Canadian study has demonstrated that the colours and texture of wood have been shown to elicit feelings of 'warmth', 'comfort' and 'relaxation' in people<sup>68</sup>, all emotions that have been shown to reduce stress, anxiety and recovery times in hospital by studies examining the influences of music<sup>59,60</sup>, plants<sup>61</sup> and therapeutic massage<sup>62</sup>
- A study in New Zealand presented 69 adults with images of 10 modern corporate interiors, chosen from recently published books showcasing contemporary design. Five of the interiors featured wood significantly, whilst the other five featured no wood at all. Participants were asked to 'identify the organisation you would most like to work for and least like to work for', followed by selecting three adjectives from a list

of 24 to indicate their first impressions of each organisation. The presence of wood products within a corporate environment considerably influenced first impressions, with study subjects significantly more likely to want to work for organisations that featured wooden furnishings. Offices with wooden interiors also conveyed feelings of innovation, energy and comfort, whilst offices without wood conveyed feelings of being impersonal and uncomfortable<sup>63</sup>.

- In a study published in 2007<sup>64</sup> participants' brain activity, blood pressure and pulse rate was monitored whilst being in a room with either 0 per cent, 45 per cent, or 90 per cent of surfaces covered with wood. All rooms showed some effect, with the blood pressure being lowest in the 90 per cent wood. The room with 45 per cent of surfaces covered with wood tended to have the highest scores in subjective comfort and restful scores. The authors concluded that this might reflect an appropriate and moderate wood quantity with which many people felt comfortable.

The positive psychological outcomes of people interacting with wooden products could have significant economic impacts. This is because studies have shown that social interactions that lead to opportunities for self-expression in old people reduces the risk of dementia, a disease that currently costs Australia over AUD\$5 billion every year and effects 44 million people worldwide<sup>65</sup>. Shortening hospital stays through reduced recovery times will also reduce costs to the medical system, whilst improved first impressions of organisations will attract business to the Australian market.

## Benefits on the Air

Wood products within a room have been shown to improve indoor air quality by moderating humidity. This effect occurs due to wood absorbing and releasing moisture in order to maintain equilibrium with the surrounding air, known as the equilibrium moisture content. Wood therefore absorbs moisture from the air in humid conditions and releases moisture in dry conditions<sup>66,67</sup>.

The ability of wood to moderate humidity is a particularly important effect in workplaces. This is because 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<sup>68</sup>. In addition, research in 2002<sup>69</sup> showed that hygroscopic wood-based materials reduced peak indoor air humidity within bedrooms at night, providing an increased level of satisfaction to their occupants.

**Figure 17. Wood products can improve indoor air quality in offices by moderating humidity.**







**Figure 18. Interior wood being used to frame views of nature.**

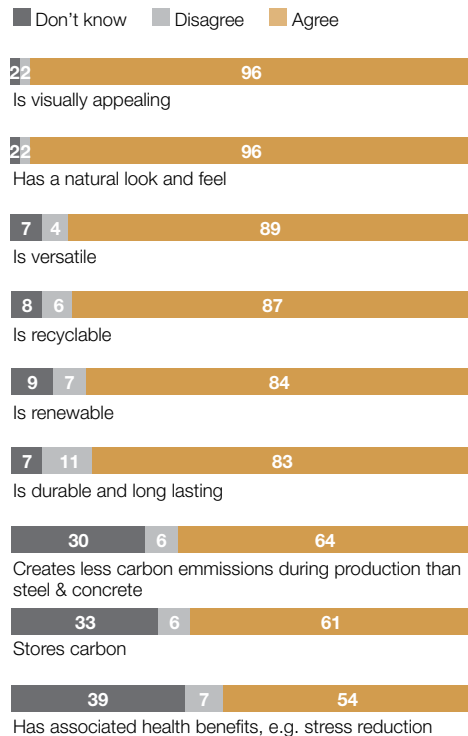
## Visual Appeal, Natural Look

Studies have identified that the presence of wood indoors is associated with an enhanced feeling of wellbeing. In aged care homes plants and natural materials (including wood) were associated with a subjective improvement in wellbeing<sup>70</sup>. Hospital rooms with wooden furniture were identified as more appealing and rated higher by their staff<sup>71</sup>. A review of photos of assisted living facilities showed that both patients and their families preferred more natural elements, including wood, on the outside of the buildings<sup>72</sup>. In a further study in which employees at a Norwegian hospital were asked to rate patients' rooms with different degrees of wood, the results indicated that patient rooms with an intermediate level of wood were the most preferred<sup>73</sup>.

Australians also appear to be innately drawn towards wood. As previously discussed, Australians identified wood use in office design contributed to greater levels of productivity<sup>38</sup>. When Planet Ark presented surveyed 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 (Figure 17), 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. The images were taken from a study by David Fell (2010), which showed Canadians have similar innate attitudes towards wood<sup>52</sup>.



**Figure 19. Images used in the Planet Ark survey of wooden and plastic furnished rooms. Sourced from David Fell (2010)<sup>52</sup>**



**Table 1. Results of the Planet Ark survey on whether Australians ‘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 Australians 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.

Australians, however, appear 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 at natural look & feel	Creates a warm & cosy environment	Visually appealing	Feels nice to touch	Environmentally friendly	Relatively cheap
<b>Wood</b>	93	92	88	87	68	31
<b>Brick</b>	61	62	58	30	47	30
<b>Concrete</b>	25	23	24	20	27	35
<b>Steel</b>	20	16	36	36	28	20
<b>Aluminium</b>	17	15	33	34	30	36
<b>Plastic</b>	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 the 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 feedback. Plastic was seen as the cheapest material but it also scored lowest in four out of five categories related



**Figure 20. We respond instinctively to the feelings of warmth and comfort and the natural look and feel of wood.**

to creating pleasant surroundings and being environmentally friendly.

These survey results provide support to the empirical evidence discussed above. Even though many people don’t understand the health and wellbeing benefits of wood they instinctively react 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.

Other similar survey studies have been performed that have shown preferences and potential positive health associations with the use of wood. A 1988 Japanese study<sup>74</sup> investigated the messages conveyed by images of wood used in residential environments. Spaces were seen as warm (i.e. pleasantly relaxed) places to be as the proportion of wooden surfaces increased up to a level of 43 per cent wood, and fell subsequently as levels rose further.

## Rating Nature Connected Design

The benefits of good building design on our health, happiness and productivity is firmly established. Indoor environment quality not only benefits the occupants but also enhances the value of the property<sup>75</sup>. This is now being reflected in building standards and rating organisations, both here in Australia and internationally.

Green Star is a program provided by the Green Building Council of Australia<sup>76</sup> (GBCA) that evaluates the sustainability qualities of a building design, construction and operation of both the building and fitout. The GBCA has been among many in the building and design community that advocate for office spaces that incorporate natural elements to improve worker wellbeing. A recent report has highlighted that many Australian offices still fall short in providing a suitable work environment.<sup>39</sup>

The WELL Building Standard<sup>TM77</sup> provides the opportunity to design and build with a human-centred approach, using an evidence-based system for measuring, certifying and monitoring the performance of building features that impact health and wellbeing.

The International organisation the Living Future Institute<sup>78</sup> has developed programmes including the living building challenge that focuses on healthy workplaces and the nature connected design principles to develop beautiful buildings.



Figure 21. The WWF Australia headquarters, situated in a century-old former wool store in inner Sydney, achieved a 5 Star Green Star Interiors rating from the GBCA.



## Cashing in on Nature Connected Design

Studies have shown that indoor environment quality is critical to the happiness of a building's occupants. This has been shown to translate into higher rental return and selling price<sup>75</sup>.

Other studies, including those by Planet Ark<sup>30</sup>, have shown that nature provides an economic value to our places of work and residences. Nature connected design may be viewed as a luxury for property owners and employers, however, in reality the benefits to be gleaned from improvements in health, reduced stress and more comfortable conditions are considerable<sup>79</sup>.

There are multiple ways by which workers can be adversely impacted by a poor environment, resulting in increased stress, loss of focus, negative mood, lower productivity, poor health and absenteeism. Studies have highlighted the high cost to Australian business from a loss in productivity from the impact of stress on the health of workers<sup>38-40</sup>. The benefit provided by nature connected design, of which the inclusion of wood is one element, is a real opportunity to improve worker health.

The positive health outcomes of people interacting with wooden products could therefore have important economic benefits. For example, social interactions that lead to opportunities for self-expression in old people reduces the risk of dementia, a disease that currently costs Australia over AUD\$5 billion every year and effects 44 million people worldwide<sup>65</sup>. Shortening hospital stays through reduced recovery times will also reduce costs to the medical system, whilst improved first impressions of organisations will attract business to the Australian market.

Figure 22. The benefits from improvements in health, reduced stress and more comfortable conditions are considerable.

## Be Certain it's Certified

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<sup>80</sup>.

The two major global forest certification bodies are the Programme for the Endorsement of Forest Certification (PEFC) and the Forest Stewardship Council (FSC). Both the 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.

In Australia, forest managers and owners have the option of certifying their forests under either the Australian Forest Certification Scheme (AFCS), which is recognised under the PEFC, or the FSC. The AFCS uses the Australian Forestry Standard (AFS) as the relevant standard for certifying forest management. FSC currently uses two interim, regionally adapted forest management standards in Australia, but is currently working towards the development of a national FSC standard for Australia. The AFCS is administered by AFS Ltd, whereas FSC certification in Australia is administered by FSC Australia.



**Figure 23. FSC, AFS and PEFC logos displayed on products made from timber and paper products derived from certified forests.**

Wood and wood-based products sourced from certified forests can also be tracked (via labelling) 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.

Like the Australian Government, Planet Ark supports all credible internationally recognised forest certification schemes that provide for legal and sustainable forest management and believes that the choice of forest certification scheme(s) is a decision for forest owners/managers.

**Figure 24. Products displaying tags to indicate they are made from FSC certified timber.**



## What About Fire Safety?

From 1 May 2016 Australia saw a change to the National Construction Code (NCC) that provides a Deemed-to-Satisfy solution for the use of timber building systems in Class 2 (apartments), Class 3 (e.g. hotels) and Class 5 (office) buildings up to 25 metres in effective height (8 storeys). New timber buildings constructed under this change are required to use fire-protective grade plasterboard and have automatic fire sprinkler systems installed. Conventional buildings of the same height are not required to have sprinklers, potentially making them less safe.

A common concern raised in regards 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<sup>81,82</sup>.

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 can ignite but 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 predictable, the wooden elements can be designed to provide greater time for escape or intervention<sup>81</sup>.

An additional benefit to heavy timber is the ease of repair after a fire. The charred sections can visually be assessed and evaluated for residual capacity, and the damaged timber can then be cut away and replaced<sup>81</sup>. This is in contrast to steel, which can buckle under the heat generated in a building fire.

In light timber frame constructions 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<sup>83</sup>.

Just because steel is a non-combustible material does not mean it is unaffected by fire. The thermal conductivity of steel is significantly greater than wood (200-1000 times higher). This creates a thermal bridging effect, allowing heat from a fire in one part of a building to spread rapidly to other parts if no protection is provided. Fire can also raise the temperature of steel to compromise its strength, with a reduction in its load carrying capacity by one third when heated above 540°C, causing beams to buckle and floors to collapse<sup>84</sup>.

A study that examined the rate of injury from hotel, motel and aged care home fires in America and Canada from 1980 to 1998<sup>85</sup> found that the presence of sprinklers had a greater impact than the combustibility of the building material (Figure 25)<sup>85</sup>. Importantly, sprinkler systems have been shown to be the one of the primary factors in limiting fatalities and fire damage in structures of all types<sup>84,86</sup>.

The presence of sprinklers had a greater impact on reducing injuries than the combustibility of the building material.



Figure 25. Deformed steel beams after a fire.

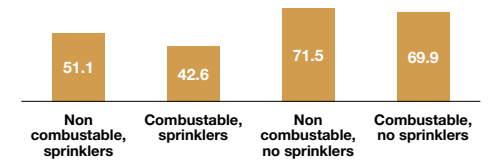


Figure 26. Injury rates (per 1,000 fires) by sprinkler protection status and building material combustibility<sup>84</sup>.

Figure 27. Sprinkler systems are one of the primary factors in limiting fatalities and fire damage in structures of all types.



## Design to Last

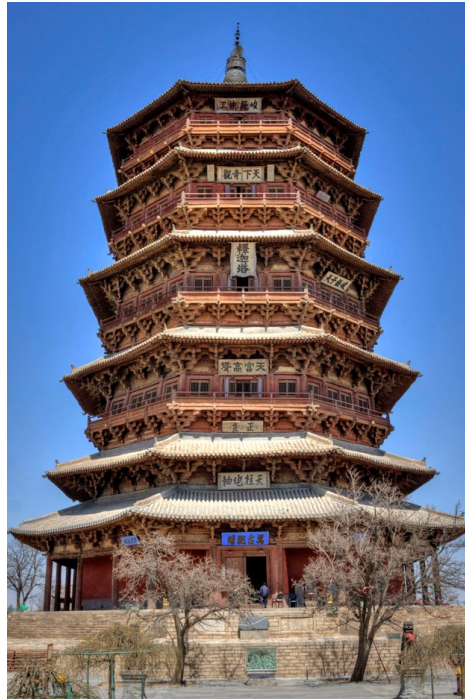
A concern sometimes raised about the use of timber is that it can be attacked by natural processes and organisms in ways that can adversely impact its durability. We know that wood and wooden buildings can last a very long time:

- The Pagoda of Fogong Temple (China) is a nine-story, 221-foot-tall pagoda located in the Shanxi province of northern China. Constructed in 1056, it is the world's oldest existing multistorey timber building.
- Urnes Stave Church (Norway) was built around 1130 and is believed to be the oldest of its kind. It provides a link between Christian architecture and the architecture and art forms of the Viking Age.

Wood can be attacked by a range of organisms including fungi, termites, beetles and a range of marine creatures as well as being subject to weathering and natural processes.

A considered approach is the use of the fit-for-purpose timber species and the correct construction techniques, which can help avoid unnecessary problems. For example, fungi will attack wood for food but require moisture, oxygen and a suitable temperature. Cutting out these essentials will help prevent decay along with choosing the most appropriate species.

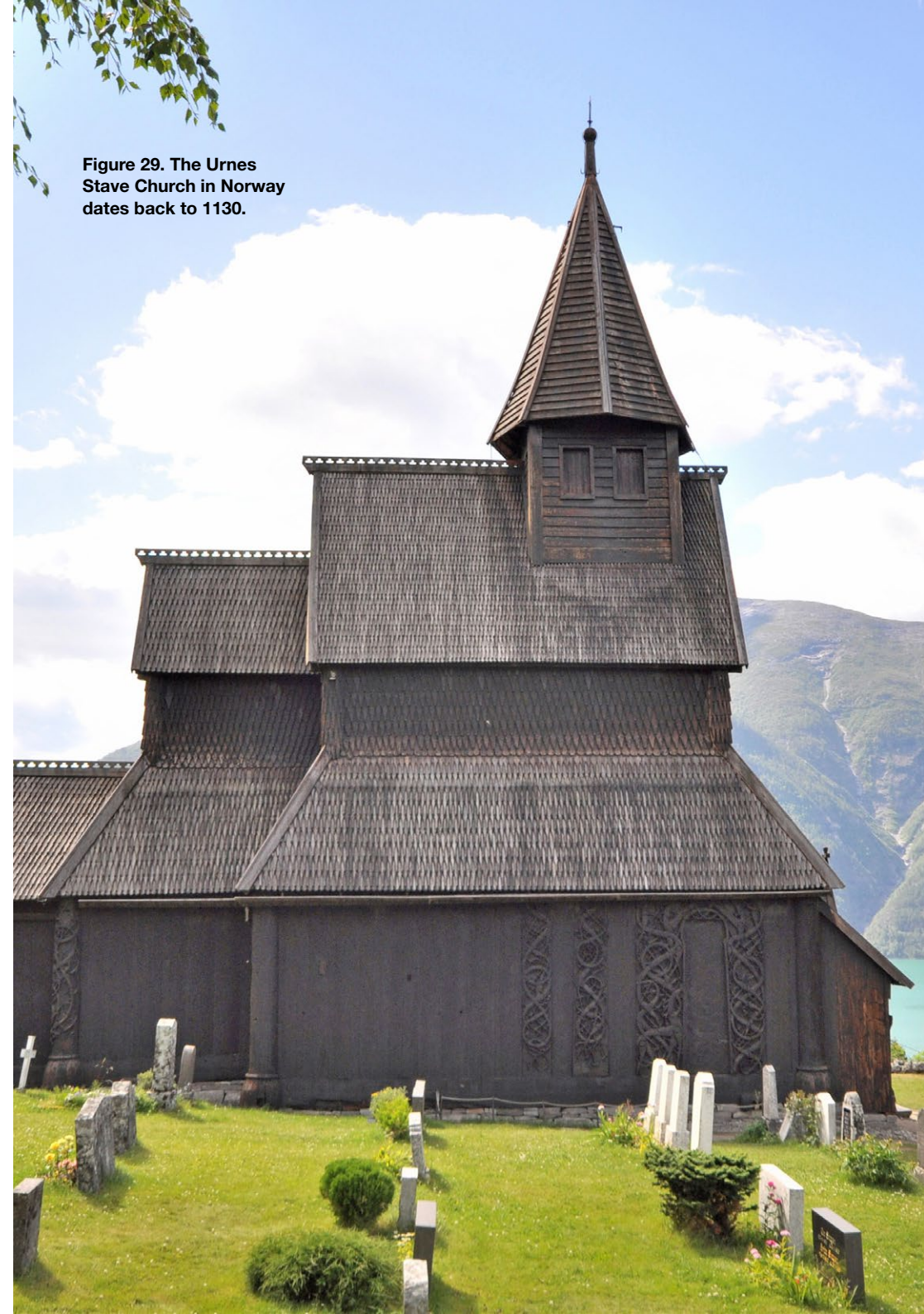
A number of species of termite are known to attack wood, for some this is via the tunnels that they build to create safe conditions for travel and transport of their food. Prevention of bridging or access points and chemical



**Figure 28. The Pagoda of Fogong Temple in China dates back to 1056.**

treatment can prevent the termites gaining pathways to their food.

Wood is a durable material for both homes and commercial buildings. When properly maintained it can last as long as other building materials. Technical design guides<sup>87</sup> and online training<sup>88, 89</sup> are available with more details on how to design for durability with timber.



**Figure 29. The Urnes Stave Church in Norway dates back to 1130.**

# Showcasing Wood

An increasing number of architects who design buildings for healing, learning and relaxation are incorporating significant amounts of wood into their structures to capitalise on its health and wellbeing benefits. Below are six Australian Exemplar Projects that showcase the use of wood in different applications, including the design ideas of those involved.

## Dandenong Mental Health Centre

The Dandenong Mental Health Centre, designed by Bates Smart and the Irwin Allsop Group, is the largest mental health facility in Victoria. Natural timber is used extensively in the walls and ceilings throughout the building, both inside and out, to create a residential and suburban feeling. This is in direct contrast to many mental health facilities that have an unnatural and institutional feel. The use of courtyards, both large and small, with wooden panels creates sized spaces that also allow light and cross ventilation into the building.

The building won the 2014 Australian Timber Design Awards due to the

combination of modern timber technology, traditional timber use and its specific design for the health benefits of wood. The judges specifically stated that; “The attention to detail is exceptional, clearly demonstrating an understanding of timber design” and that “The design team demonstrated an understanding of the health benefits of wood.”

Bates Smart and the Irwin Allsop Group said that they specifically chose wood, both new and recycled, to provide warmth, texture, patterning, tactility and a non-institutional feel to the facility. In addition they stated that wood is durable, low maintenance and has already begun to age gracefully<sup>90</sup>.



Figure 30. Natural timber is used extensively throughout the building, both inside and out, to create a residential and suburban feeling.



# Marist College Bendigo Montagne Centre

The 2016 Australian Timber Design Sustainability Category was awarded to Matt Dwyer and Garry Thompson from Y2 Architecture and Paul Waddell from Three Acres Landscape Architecture for the Marist College Bendigo Montagne Centre. This is a wonderful example of timber used in a nature connected design creating the connection between the school and the environment.

This building combines the use of timber in a design that connects the internal and external environments. Ironbark and Spotted Gum recycled telephone poles are used to support the exposed primary and secondary glulam timber trusses. Silvertop ash cladding is used around the perimeter of the building as a durable, sustainable and thermally efficient material. Glulam and LVL trusses used through the centre relate back to the Marist traditions of conventional construction techniques and closeness with natural materials.

Marist College is linked to water by implementing a system of wetlands and bio-filtration that weaves through the site and is used for on-site treatment of water and storage/use of rainwater. The wetlands provide an ecosystem that breathes life into the school site with native reeds and aquatic plants forming a lush habitat for the local fauna. The eucalypt woodlands found around the site consists of native tree species such as ironbark, yellow box and river red gum.

The school embraces the Reggio Emilia<sup>91</sup> approach to education in which the environment is seen as the third teacher. This applies equally to the inside and outside environments by placing value on aesthetics, organisation, thoughtfulness, provocation, communication and interaction. Care and attention paid to organising space outdoors stimulates children's imagination, creativity, exploration, discovery, engagement and sense of wonder.

According to Darren McGregor, Principal at Marist College, Bendigo; "The building and the atmosphere that has been created has had a noticeably calming effect on the students."

**Figure 31. The Marist College Bendigo Montagne Centre combines the use of timber in a design that connects the internal and external environments.**



## Melbourne School of Design

2015 Australian Timber Design Award was presented to John Wardle Architects and NADAAA for the Melbourne School of Design, an inspiring example of sound, passive green design practices. The design aspires to both educate the building users and to provide a catalyst for learning. The use of timber in the building incorporates a variety of applications ranging from exposed structural components down to smaller scaled and highly detailed elements.

The design principles adopted for building reflects the local climate by utilising diurnal variation, natural ventilation, thermal mass, daylight, and optimal sun shading to create a learning environment attuned to its climatic context. The transparency of the building supports the vision of a living/learning space. This is expressed in the use of mesh balustrades to the atrium edges, the open ground floor exhibition gallery, and the opening up of the buildings functions at the building perimeter.

The building is a showcase of what can be achieved with structural timber. Engineered timber beams and coffers span its 20-metre wide atrium, acting as sunshades, structural restraints, and structural support for the atrium roof glazing. The timber framed and lined hanging studio is suspended from two of the overhead engineered timber beams, whilst the custom detailed perforations and folds of the hanging studio envelope works to meet the acoustic tuning of the atrium space.

The use of sustainably sourced renewable timber contributes to the reduction in the buildings embodied energy and was an important contributor for the building achieving a 6 Star Green Star rating.

Figure 32. The design of Melbourne School of Design aspires to both educate the users and also to provide a catalyst for learning.





## The Village Centre, National Arboretum, Canberra

Winner of the 2013 Central Region Timber Design Award and designed by Peter Tonkin of Tonkin Zulaikha Greer Architects, the Village Centre nestles into the landscape just below the site's ridgeline to complement the surrounding topography. The building creates a strong sense of indoor-outdoor connection, contrasting a high arching roof and huge windows with low stone-clad walls.

Internally, the unique timber structure combines a low environmental impact with dramatic forest-like forms, designed in a series of geometrical arcs, inspired by the leaves and trees in the surrounding forests. The timber frame uses laminated Tasmanian oak and contains over 3,000 unique structural members, cut to shape from computer models, test fitted in factories in Tasmania and then erected on site.

All ten massive curved beams in the ceiling are of different lengths, and 73 solid timber struts form the key structural elements of the dome. The longest beam is 56 metres long and 12 metres high.

The biomorphic forms within the centre, the use of stone and the interconnectedness of natural elements have created an excellent example of nature connected design.

**Figure 33. The biomorphic forms within the Village Centre, National Arboretum Canberra provide an excellent example of nature connected design.**

## Tempe House, Tempe, NSW

Tempe House was intentionally designed to be small to minimise its environmental impact and construction budget. The designer was able to reduce the impact of the development by careful retention and restoration of the existing dwelling, including the original kitchen and bathroom locations, and the rationalisation of the floor plan to create a single line of circulation and a small, efficient staircase. Importantly, the orientation of the design maximised the northern and western openings to capture winter sunlight and summer breezes.

A number of other design features helped to ensure that the design had the least possible impact on the environment, including the use of double-glazing and increased insulation, including floor insulation. The house also has a 2000 litre rainwater storage tank which was located internally so that its thermal mass could be used to regulate the internal temperature of the home, and to store the heat from penetrating winter sunlight.

The majority of the project was hand crafted on site, which ensured a high level of control of on-site waste and an opportunity for maximum reuse and recycling. Timber elements were either screw, bolt or threaded rod fixed to enable simple disassembly and potential reuse at the end of life.

Careful use of exposed timber elements and outdoor views has created a calming, tranquil environment and an exquisite example of nature connected design.



Figure 34. Careful use of exposed timber elements and outdoor views has created a calming, tranquil environment and an exquisite example of nature connected design.



## The Library at the Dock, Victoria Harbour, Melbourne

The library at the dock was the winner of the Sustainability Category in the 2014 Australian Timber Design Awards. The project was delivered through a unique tri-partnership between the City of Melbourne, Lendlease and the state government through Places Victoria. It was designed by Clare Design, with Hayball engaged as architect of record.

The library set new environmental benchmarks as Australia's most sustainable community building, constructed primarily from cross-laminated timber (CLT) and recycled hardwood. The unique contrast of reclaimed old timber with the latest innovation of CLT construction celebrates history while embracing 21st century technology. Library at The Dock was Australia's first public building made from CLT.

The three-storey library is situated on the waterfront of Victoria Harbour in Melbourne's

Docklands. As well as a traditional library collection, the library offers an interactive learning environment, an impressive digital collection, and multi-purpose community spaces and a performance venue that holds 120 people.

The library was built by Lendlease using 1,000 cubic metres of European Spruce CLT. The façade consists of recycled Ironbark and Tallowwood timber to complement the promenade decking. The decking is made from reclaimed timber from the Victoria Harbour south wharf, giving new life to the local area's historical past.

Construction right on the waterfront, just eight metres from the edge, was only possible because CLT is 20 per cent of the weight of traditional structures, significantly reducing the requirement for new substructure. The 75-year-old wharf has been preserved and serves as the building's substructure.

The use of CLT for the library's structure significantly reduced the building's carbon footprint. In addition, the building's passive design promotes natural ventilation, daylight and fresh indoor air quality, resulting in reduced energy consumption and an improved indoor environment.

The building has achieved a Six Star Green Star rating under the public buildings rating tool from the Green Building Council of Australia.

**Figure 35. The Library at the Dock's passive design promotes natural ventilation, daylight and fresh indoor air quality, resulting in reduced energy consumption and an improved indoor environment.**

# Conclusion

Wood has entered a new era where, with good design and modern engineering techniques, it can be used to create extraordinary structures. Through the incorporation of nature connected design, these designs can help to create positive and healthy environments. Timber can not only provide the structure for a building, but can also be used to reflect nature's shapes and aesthetics. Indeed, just through the presence of wood we can deliver healthier environments.

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.

These benefits are particularly important for environments where it is difficult to incorporate nature indoors, such as hospitals, where strict health and safety guidelines may prevent the presence of plants, and office environments where views from the window are of roads and neighbouring concrete buildings.

Responsibly sourced (and certified) timber has clear health and happiness benefits, as well as being a weapon in the struggle against climate change by both storing carbon and reducing carbon emissions.

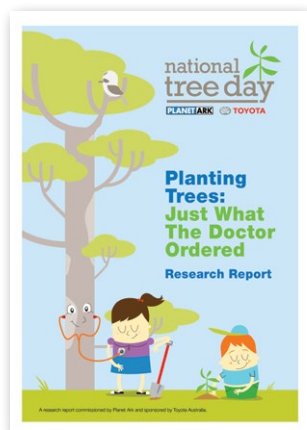
Wood is one of the oldest and most versatile building materials used by humanity, but now more than ever it has a large part to play in the design and construction of healthy buildings for us to live, work, learn and recover in.

**Figure 36. Responsibly sourced (and certified) timber has clear health and happiness benefits.**



# Planet Ark Nature Related Research

Planet Ark has undertaken and commissioned a number of reports focusing on the health and wellbeing benefits of contact with nature for people from across the entire community. On the whole this research focused on exposure to natural elements like plants, gardens, wilderness, nature views and so on. The addition of this new report, focusing as it does on the benefits of wood in the built environment continues to build on our understanding of the human connection to nature. Our previous reports include:



2012 - **Planting Trees: Just What The Doctor Ordered**, which explored the intellectual, psychological, physical and mental health benefits of contact with nature for children.



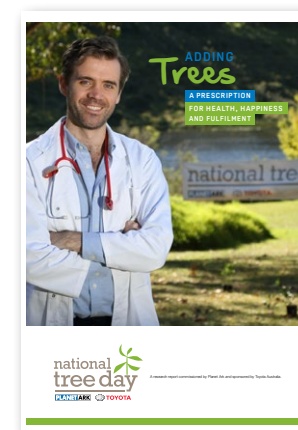
2013 - **Missing Trees: The Inside Story of an Outdoor Nation**, which focused on outdoor recreation and contact with nature, among adults as well as children. Key areas included: the backyard and its decline in Australia; whether the great outdoors is still a key part of how we view ourselves as Australians; and whether there is a link between backyards and the amount of time people spend doing outdoor recreational activities.



2014 - **Valuing Trees: What is nature worth?** which took a broader focus and looked at the economic, environmental, health and social benefits of nature in the workplace, at home, in neighbourhoods and in schools. The report examined how much Australians value nature and outlined the results of an independent survey that explored the financial figures people are willing to allocate to these benefits.



2015 - **Needing Trees - The Nature of Happiness** which investigated how contact with nature affects people's life-long happiness and the physiological impacts it has on the brain. It found that spending time in nature influences our subjective wellbeing, which has long-term health and financial consequences.



2016 - **Adding Trees - A Prescription for Health, Happiness and Fulfilment**, which examined how time in nature enhances and grows the key areas in life that Australians consider the most important for a fulfilling life – health, happiness, learning, relaxation and relationships.

# References

- Fromm, E. *The Heart of Man*. (Harper & Row., 1964).
- Wilson, E. O. *Biophilia*. (Cambridge, Mass: Harvard University Press, 1984).
- Kellert, S. R., Heerwagen, J. & Mador, M. *Biophilic design: the theory, science and practice of bringing buildings to life*. (John Wiley & Sons, 2011).
- Carre, A. *A comparative life cycle assessment of alternative constructions of a typical Australian house design*. (Forest and Wood Products Australia, 2011).
- Durlinger, B., Crossin, E. & Wong, J. Life Cycle Assessment of a cross laminated timber building. *fwpa.com.au* Available at: [http://www.fwpa.com.au/sites/default/files/PRA282-1112\\_Life-Cycle\\_Assessment\\_of\\_a\\_cross\\_laminated\\_timber\\_building\\_0.pdf](http://www.fwpa.com.au/sites/default/files/PRA282-1112_Life-Cycle_Assessment_of_a_cross_laminated_timber_building_0.pdf).
- Adding Trees: A prescription for health, happiness and fulfillment*. 1–29 (2016).
- Zelenski, J. M. & Nisbet, E. K. Happiness and Feeling Connected: The Distinct Role of Nature Relatedness. *Environment and Behaviour* **46**, 3–23 (2014).
- Zhang, J. W., Howell, R. T. & Iyer, R. Engagement with natural beauty moderates the positive relation between connectedness with nature and psychological well-being. *Journal of Environmental Psychology* **38**, 55–63 (2014).
- Berman, M. G., Jonides, J. & Kaplan, S. The Cognitive Benefits of Interacting with Nature. *Association for Psychological Science* **19**, 1207–1212 (2008).
- Berman, M. G. *et al.* Interacting with nature improves cognition and affect for individuals with depression. *Journal of Affective Disorders* **140**, 300–305 (2012).
- Tsao, T.-M. *et al.* The health effects of a forest environment on subclinical cardiovascular disease and health-related quality of life. *PLoS ONE* **9**, e103231–e103231 (2013).
- Lee, J., Park, B.-J., Tsunetsugu, Y., Kagawa, T. & Miyazaki, Y. Restorative effects of viewing real forest landscapes, based on a comparison with urban landscapes. *Scandinavian Journal of Forest Research* **24**, 227–234 (2009).
- E. O. Wilson Biography Wikipedia. 1–12 (2016).
- Ng, M. Global, regional, and national prevalence of overweight and obesity in children and adults during 1980–2013: a systematic analysis for the Global Burden of Disease Study 2013. *The Lancet* **384**, 766–781 (2014).
- Depression and anxiety are common conditions. *BeyondBlue.org.au* Available at: <http://www.beyondblue.org.au/the-facts>. 16.
- Ulrich, R. S. View through a window may influence recovery from surgery. *Science* **224**, 420–421 (1984).
- Kjaersti Raanaas, R., Grindal Patil, G. & Hartig, T. Health benefits of a view of nature through the window: a quasi-experimental study of patients in a residential rehabilitation centre. *Clinical Rehabilitation* **26**, 21–32 (2011).
- Aries, M. B. C., Veitch, J. A. & Newsham, G. R. Windows, view and office characteristics predict physical and psychological discomfort. *Journal of Environmental Psychology* **30**, 533–541 (2010).
- Kjaersti Raanaas, R., Evensen, K. H., Rich, D., Sjostrom, G. & Patil, G. Benefits of indoor plants on attention capacity in an office setting. *Journal of Environmental Psychology* **31**, 99–105 (2011).
- Park, S. H., Mattson, R. H. & Kim, E. Pain tolerance effects of ornamental plants in a simulated hospital patient room. *Acta Horticulturae* **639**, 241–247 (2004).
- Park, S. H. & Mattson, R. H. Effects of flowering and foliage plants in hospital rooms on patients recovering from abdominal surgery. *HortTechnology* **18**, (2008).
- Block, A. H., Livesley, S. J. & Williams, N. S. G. *Responding to the urban heat island: a review of the potential of green infrastructure*. Victorian Centre For Climate Change Adaptation research (2012).
- Newman, P., Hargroves, K., Desha, C. & Reeve, A. *Can biophilic urbanism deliver strong economic and social benefits in cities?* (2012).
- Shanahan, D. F., Fuller, R. A., Bush, R., Lin, B. B. & Gaston, K. J. The health benefits of urban nature: how much do we need? *BioScience* **6**, 476–485 (2015).
- McDonald, R., Kroeger, T., Boucher, T., Longzhu, W. & Salem, R. *Planting healthy air: a global analysis of the role of urban trees in addressing particulate matter pollution and extreme heat*. (2016).
- Where are all the Trees? An analysis of tree canopy cover in urban Australia*. 1–30 (Vision2020, 2014).
- The 2020 Vision Plan*. 1–57 (2020 Vision, 2015).
- Do it on the roof. *doitontheroof.com* Available at: <http://www.doitontheroof.com/>.
- el-Baghdadli, O. & Desha, C. Stacking the business case for biophilic urbanism. *thefifthestate.com.au* Available at: <http://www.thefifthestate.com.au/columns/spinifex/stacking-the-business-case-for-biophilic-urbanism/87851>.
- Levin, J. *Valuing Trees: What Is Nature Worth?* (Planet Ark, 2014).
- Kellert, S. R. & Finnegan, B. Biophilic Design: The Architecture of Life. 1–7 (2011).
- Kellert, S. R. & Calabrese, E. F. The Practice of Biophilic Design. 1–27 (2015).
- Kaplan, R. & Kaplan, S. *The Experience of Nature: A Psychological Perspective*. (Cambridge University Press, 1989).
- Joye, Y. & van den Berg, A. in *Environmental psychology: An introduction* (2012).
- Gifford, R. & McCunn, L. J. *Appraisals of built environments and approaches to building design that promote well-being and healthy behaviour*. (Environmental Psychology: An Introduction, 2012).
- Gillis, K. & Gatersleben, B. A Review of Psychological Literature on the Health and Wellbeing Benefits of Biophilic Design. *Buildings* **5**, 948–963 (2015).
- Browning, W., Ryan, C. & Clancy, J. *14 Patterns of Biophilic Design: Improving Health & Well being in the Built Environment*. (2014).
- Cooper, C. & Browning, B. *HUMAN SPACES: The Global Impact of Biophilic Design in the Workplace*. 1–48 (2015).
- The health of Australia's workforce*. 1–12 (Medibank Private, 2005).
- The Cost of Workplace Stress in Australia*. (Medibank Private, 2008).
- National Arboretum Canberra: Fact Sheet - Buildings. 1–4 Available at:
- Tonkin, P., Chesterman, J., Wolter, J., Taylor, T. & OSullivan, R. National Arboretum : Village Centre. Tonkin Zulaikha Greer Architects. *tzg.com.au* Available at: <http://www.tzg.com.au/project/arboretum-village-centre/>.
- Ward, L. A Tree-Filled Atrium to Inspire Patients. (2014). Available at: [http://www.architectmagazine.com/technology/detail/a-tree-filled-atrium-to-inspire-patients\\_o](http://www.architectmagazine.com/technology/detail/a-tree-filled-atrium-to-inspire-patients_o).
- Edelstein, E. A. Neuro-architecture. *worldhealthdesign.com* Available at: <http://www.worldhealthdesign.com/Neuro-architecture.aspx>.
- Obata, Y., Takeuchi, K., Furuta, Y. & Kanayama, K. Research on better use of wood for sustainable development: Quantitative evaluation of good tactile warmth of wood. *Energy* **30**, 1317–1328 (2005).
- Nousiainen, M. *Restorative Environment Project Part 1*. 1–25 (2013).
- Augustin, S. & Fell, D. *Wood as a Restorative Material in Healthcare Environments*. 1–33 (2016).
- Sakuragawa, S., Miyazaki, Y., Kaneko, T. & Makita, T. Influence of wood wall panels on physiological and psychological responses. *Journal of Wood Science* **51**, 136–140 (2005).
- Positive health effects of Stone Pine furniture*. (Joanneum Research Institute of Non-Invasive Diagnosis, 2012).
- Kelz, C., Grote, V. & Moser, M. Interior wood use in classrooms reduces pupils' stress levels. (2011).
- Ohta, H. *et al.* Effects of redecoration of a hospital isolation room with natural materials on stress levels of denizens in cold season. *Int J Biometeorol* **52**, 331–340 (2008).
- Fell, D. R. Wood in the human environment: Restorative properties of wood in the built indoor environment. (The University of British Columbia, 2010).
- Kyrou, I. & Tsigos, C. Stress hormones: physiological stress and regulation of metabolism. *Current Opinion in Pharmacology* **9**, 787–793 (2009).
- Lupien, S. J., McEwen, B. S., Gunnar, M. R. & Heim, C. Effects of stress throughout the lifespan on the brain, behaviour and cognition. *Nature Reviews Neuroscience* **10**, 434–445 (2009).
- Pervanidou, P. & Chrousos, G. P. Metabolic consequences of stress during childhood and adolescence. *Metabolism* **61**, 611–619 (2012).
- Elias, M. J. Schools as a source of stress to children: An analysis of causal and ameliorative influences. *Journal of school psychology* **27**, 393–407 (1990).
- Anne, T. *et al.* Behaviour Changes in Older Persons Caused by Using Wood Products in Assisted Living. *Public Health Research* **2**, 106–109 (2012).
- Rice, J., Kozak, R. A., Meitner, M. J. & Cohen, D. H. Appearance Wood Products and Psychological Well-Being. *Wood and Fiber Science* **38**, 644–659 (2007).
- McCaffrey, R. The effect of music on acute confusion in older adults after hip or knee surgery. *Applied Nursing Research* **22**, 107–112 (2009).
- Bolwerk, C. A. Effects of relaxing music on state anxiety in myocardial infarction patients. *Crit Care Nurs Q* **13**, 63–72 (1990).
- Park, S.-H. & Mattson, R. H. Therapeutic Influences of Plants in Hospital Rooms on Surgical Recovery. *HortScience* **44**, 102–105 (2009).
- Post-White, J. *et al.* Therapeutic Massage and Healing Touch Improve Symptoms in Cancer. *Integr cancer ther* **2**, 332–344 (2003).
- Ridoutt, B. G., Ball, R. D. & Killerby, S. K. First impressions of organizations and the qualities connoted by wood in interior design. *Forest Products Journal* 1–9 (2002).
- Tsunetsugu, Y., Miyazaki, Y. & Sato, H. Physiological effects in humans induced by the visual stimulation of room interiors with different wood quantities. *Journal of Wood Science* **53**, 11–16 (2007).
- Dementia and memory loss statistics. (2014). Available at: <https://flightdementia.org.au/about-dementia-and-memory-loss/statistics>.
- Health and Well-being: Building Green with Wood Module 6*. 1–4 (reThink Wood, 2015).
- Equilibrium Moisture Content in Outdoor Locations in the United States and Worldwide*. (Forest Products Laboratory (U.S.), 1998).
- Bergs, J. Effect of healthy workplaces on well-being and productivity of office workers. in (2002).
- Simonson, C. J., Salonvaara, M. & Ojanen, T. The effect of structures on indoor humidity—possibility to improve comfort and perceived air quality. *Indoor Air* **12**, 243–251 (2002).
- Weenig, M. W. H. & Staats, H. The impact of a refurbishment of two communal spaces in a care home on residents' subjective well-being. *Journal of Environmental Psychology* **30**, 542–552 (2010).
- Swan, J. E., Richardson, L. D. & Hutton, J. D. Do appealing hospital rooms increase patient evaluations of physicians, nurses, and hospital services? *Health Care Manage Rev* **28**, 254–264 (2003).
- Marsden, J. P. Older persons' and family members' perceptions of homeliness in assisted living. *Environment and Behavior* **31**, 84–106 (1999).
- Bringslimark, T. & Nyruud, A. Q. Patient rooms with different degrees of wood: A preference study conducted among hospital staff. *WCETE 2010 World Conference ...* (2010).
- Masuda, M. & Nakamura, M. The wood ratio in interior space and the psychological images. *Bulletin of the Kyoto University Forests* (1988).
- Eichholtz, P., Kok, N. & Quigley, J. M. Doing well by doing good? Green office buildings. *The American Economic Review* (2010). doi:10.1257/aer.100.5.2494
- Global study connects levels of employee productivity and well-being to office design - Green Building Council Australia (GBCA). Available at: <https://www.gbca.org.au/news/>
- gbca-news/global-study-connects-levels-of-employee-productivity-and-wellbeing-to-office-design/.
- WELL Building Standard® | International WELL Building Institute. *wellcertified.com* Available at: <https://www.wellcertified.com/well>.
- The Living Future Institute Homepage. *living-future.org* Available at: <https://living-future.org/>.
- Browning, W. D., Kallianpurkar, N., Ryan, C. O. & Labruto, L. *The Economics of Biophilia*. (New York, 2012).
- Make It Wood: Making the Right Choice. *makeitwood.org* Available at: <http://makeitwood.org/choosing-wood/>.
- Gerard, R., Barber, D. & Wolski, A. *Fire safety challenges of tall wood buildings*. (2013).
- Calculating the fire resistance of exposed wood members*. (American Wood Council, 2016).
- Buchanan, A. *Fire Resistance of Timber Structures*. National Institute of Standards and Technology 1–20 (2014).
- Maxim, P., Plecas, D., Garis, L. & Clare, J. *Taller Wood Buildings and Fire Safety*. (2013).
- Richardson, L. R. Fire losses in selected property classifications of non-residential, commercial and residential wood buildings. Part 1: hotels/motels and care homes for aged. *Fire and Materials* **31**, 97–123 (2007).
- Frangi, A. & Fontana, M. Fire Performance Of Timber Structures Under Natural Fire Conditions. *Fire Safety Science* **8**, 279–290 (2005).
- Mackenzie, C., Wang, C. H., Leicester, R. H., Foliante, G. C. & Nguyen, M. N. *05 Timber service life design. Design guide for durability*. 1–104 (Wood Solutions, 2015).
- Nolan, G. Design for Durability. in 1–60 (2011).
- Nolan, G. WoodSolutions Campus. Available at: <https://campus.woodsolutions.com.au/>.
- 2014 Australian Timber Design Award Overall Winner. *timberawards.com.au* (2014). Available at: <http://www.timberawards.com.au/news/21-2014-awards-news/168-2014-australian-timber-design-award-overall-winner>.
- Reggio Emilia approach - Wikipedia. *Wikipedia* Available at: [https://en.wikipedia.org/wiki/Reggio\\_Emia\\_approach](https://en.wikipedia.org/wiki/Reggio_Emia_approach).
- <http://www.environment.gov.au/topics/environment-protection/air-quality/indoor-air>



# Index of Photographs

Figure	Project	Designer	Photographer
Cover page	Melbourne School of Design – the University of Melbourne	John Wardle Architects and NADAAA in collaboration	Peter Bennetts
Figure 1	Bold Park Aquatic Centre, City Beach, WA	Donovan Payne Architects & Andrew Volkman & Kim Donovan	Emma Van Dordrecht – F22 Photography
Figure 2	Swadling House, Matraville, NSW		Ian Wingrove and Associates
Figure 3	John Septimus Roe Anglican Community School Senior Learning Centre, WA	Brooking Design Architects	Heather Robbins
Figure 4	Library at the Dock, Victoria Harbour, Melbourne	Lendlease with Clare Design and Hayball	Dianna Snape and Emma Cross
Figure 5	Marist College Bendigo Montagne Centre, Victoria	Y2 Architecture and Three Acres Landscape Architecture	Bill Conroy, Press 1 Photography
Figure 6	CLT House, Maianbar, NSW	Ardea Oosthuizen	Josh Hill Photography
Figure 7	Breathing wall at the Lendlease Head Office, International Towers Sydney, Barangaroo, Sydney	Lendlease	Image courtesy of Lendlease
Figure 8	Dandenong Mental Health Facility, Dandenong	Bates Smart (in collaboration with Irwin Alsop group)	John Gollings, Peter Bennetts
Figure 9	Woodleigh School Senior Homestead, Langwarrin South, Victoria	Law Architects	Drew Echberg
Figure 10	Credit Valley Hospital Regional Cancer Centre, Ontario, Canada	Farrow Partners	Courtesy of Farrow Partners
Figure 11	Metropol Parasol in Seville, Spain	J. Meyer. H Architects	Courtesy of J. Meyer. H Architects
Figure 12	Saffire Resort, Freycinet, Tasmania	Circa Morris-Nunn Architects	George Apostolidis
Figure 13	Woodleigh School Senior Homestead, Langwarrin South, Victoria	Law Architects	Drew Echberg
Figure 14	Tempe House, Sydney, NSW	Pederson Architecture	Thilo Pulch
Figure 15	John Septimus Roe Anglican Community School Kindergarten, WA	Brooking Design Architects	Heather Robbins
Figure 17	Ansarada Office, Sydney	Those Architects and End of Work	Brett Boardman Photography
Figure 18	Tempe House, Sydney, NSW	Pederson Architecture	Thilo Pulch
Figure 20	Woodleigh School Senior Homestead, Langwarrin South, Victoria	Law Architects	Drew Echberg
Figure 21	WWF Australia Headquarters, Sydney	DesignEco	
Figure 22	Library at the Dock, Victoria Harbour, Melbourne	Lendlease with Clare Design and Hayball	Dianna Snape and Emma Cross
Figure 30	Dandenong Mental Health Facility, Dandenong	Bates Smart (in collaboration with Irwin Alsop group)	John Gollings, Peter Bennetts
Figure 31	Marist College Bendigo Montagne Centre	Y2 Architecture and Three Acres Landscape Architecture	Bill Conroy, Press 1 Photography
Figure 32	Melbourne School of Design – the University of Melbourne	John Wardle Architects and NADAAA in collaboration	Peter Bennetts
Figure 33	The Village Centre, National Arboretum, Canberra	Tonkin Zulaikha Greer Architects	Brett Boardman Photography
Figure 34	Tempe House, Sydney, NSW	Pederson Architecture	Thilo Pulch
Figure 35	Library at the Dock, Victoria Harbour, Melbourne	Lendlease with Clare Design and Hayball	Dianna Snape and Emma Cross
Figure 36	John Septimus Roe Anglican Community School Senior Learning Centre, WA	Brooking Design Architects	Heather Robbins