J. W. Gottstein Memorial Trust Fund

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GOTTSTEIN TRUST

Improving the durability performance of engineered wood products: A study tour of Europe and North America

By

WILLIAM LEGGATE

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Joseph William Gottstein Memorial Trust Fund

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Bill Gottstein was an outstanding forest products research scientist working with the Division of Forest Products of the Commonwealth Scientific Industrial Research Organization (CSIRO) when tragically he was killed in 1971 photographing a tree-felling operation in New Guinea. He was held in such high esteem by the industry that he had assisted for many years that substantial financial support to establish an Educational Trust Fund to perpetuate his name was promptly forthcoming.

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About the Author

William Leggate is a forest products research scientist, with particular interest in wood protection and durability.

William has over twenty years of involvement in the Australian and international timber industry working in research, technical, commercial and management roles. This has included experience in the timber industries of South and Central America, Solomon Islands, Papua New Guinea, Laos and Vietnam.

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Abstract

Engineered wood products (EWPs) are rapidly growing global market share in both structural and appearance end-uses. These products are formed by combining wood components such as flakes, fibres, particles, veneers, strands, rounds or sawntimber into composite products. Often these composite products can also feature non-wood components such as glues, metals and plastics. Examples of EWPs include cross laminated timber (CLT), glulam, plywood, laminated veneer lumber (LVL), oriented strandboard (OSB), particleboard and I beams. These products are used in diverse applications, including construction, flooring, walls, roofs, linings, decorative architectural features, furniture, packaging, utility poles, cross-arms and bridges. The reasons for their growing popularity are multi-faceted and include numerous performance, resource conversion and sustainability advantages.

However, as the use of EWPs expands, so too do concerns about their long-term durability performance. This report describes the outcomes of a study of EWP production, use and R&D in Europe and North America with a special focus on wood protection measures adopted to maximise EWP durability performance. The current status quo and implications for the Australian industry are also described.

Key findings are:

- Because EWPs contain wood, they are subject to the same deterioration agents that effect all wood products. This includes damage by fungi, insects, fire and weathering. However, the impact of these degradation agents on EWPs is not always the same as for solid wood products. This is because EWPs also usually contain glue and have different geometries and configurations compared to solid wood products. Additionally, the manufacturing process adopted for some EWPs involving log pre-conditioning, high temperature and pressure during product forming and pressing can also impact on EWP durability.
- The vast majority of EWPs in Europe and North America are not preservative treated and are used internally or in weather-protected situations. However, EWPs are preservative treated if used in exposed, hazardous situations requiring longer service lives or in some cases, for particular applications, if exported to countries such as Australia.
- The main focus of the wood preservative treatment industries of Europe and North America is currently solid wood products, not EWPs.
- There is a greater reliance on design, construction, detailing, finishing, maintenance and monitoring approaches rather than wood preservative treatment to maximise durability performance of EWPs. However, there is an increasing call to mandate preservative treatment of EWPs such as CLT and other massive timber elements where they are used as structurally critical elements and in difficult to access situations. This is because it is acknowledged that there are often failures in the

above-mentioned control measures and precautionary treatments would help to avoid the serious, potentially catastrophic consequences of EWP failure.

- Various preservative treatment methods are adopted for EWPs including:
    - Treatment of feedstock before gluing and product manufacture
    - Treatment during product manufacture
    - Treatment after product manufacture
    - Combinations of the above
- There is increasing global pressure to reduce the use of biocides, and concerns over growing restrictions which will limit future availability of wood preservatives that are currently in use. This is particularly the case in Europe. For this reason, wood preservation R&D in Europe is predominantly concerned with wood modification and novel alternative, non-biocidal treatment measures.
- In Europe and North America, weathering degrade of wood products is a major concern and there is a greater focus than in Australia on finishing systems to reduce wood degradation (e.g. from weathering and decay) and to maximise the appearance performance and aesthetic appeal of wood products.
- Globally, changing climatic conditions are projected to increase wood degradation hazards and concomitantly raise the importance of R&D to provide solutions.
- EWP producers recognise the potential to greatly expand their market-share if more optimal and affordable wood protection options can be found.

Keywords:

Engineered wood products, durability, wood preservation

Table of Contents

Glossary

Engineered Wood Products (EWPs) - For the purposes of this report, Engineered Wood Products (EWPs) are defined as timber composites formed from various wood components (and sometimes non-wood components such as plastic and metals) in combination with adhesives. Wood components of EWPs consisting of sawn laminates, veneers, strands, particles, flakes or fibres are reconstituted together with adhesives, usually involving heat and/or pressure, into both structural and appearance sections. EWPs generally take the form of panels, rectangular sections and I-beams (Bolden and Greaves, 2008).

Durability - The Australian Building Codes Board (ABCB) defines durability as "capability to perform a function over a specified period of time" (ABCB, 2015). This definition is adopted for this report, consequently wood durability is discussed in the context of both structural and aesthetic performance encompassing factors such as decay, termites, borers, moulds, weathering, glueline failures, dimensional instability, fire and corrosion of fasteners.

Wood treatment – Unless otherwise stated, for this report, wood treatment refers to the treatment of wood using conventional chemical preservatives and processes mainly to provide protection against wood degradation caused by biological agents.

Wood modification – For this report, wood modification refers to chemical, physical and biological processes that modify wood to obtain desired property improvements for service life – mode of action is generally non-biocidal and non-toxic (Dunningham and Sargent, 2015).

Wood protection – For this report, wood protection refers to any measures taken to protect wood from degradation due to biological and/or physical agents.

Introduction

There is a booming demand worldwide for Engineered Wood Products (EWPs) to be used in buildings and other structures. This is occurring because of the many advantages of EWPs compared to solid wood products and other alternative building materials. Some of the principal advantages compared to solid wood products are:

- they can be manufactured from lower grade wood resources and small pieces;
- much greater flexibility in product dimension possibilities;
- reduced waste and higher recoveries of product; and
- higher design strengths, greater uniformity and substantially reduced variation in structural properties.

Compared to solid wood, lighter-weight EWPs can also compete more cost effectively against alternative building materials such as concrete and steel in commercial and multi-residential buildings. EWPs are also characterised by all the benefits of wood in general – i.e. a natural, renewable resource, low embodied energy, carbon capture, aesthetics, warmth, relatively low costs and workability.

Figure 1 shows the spectacular rise in global production of CLT, one of the EWPs which generates the most media attention.

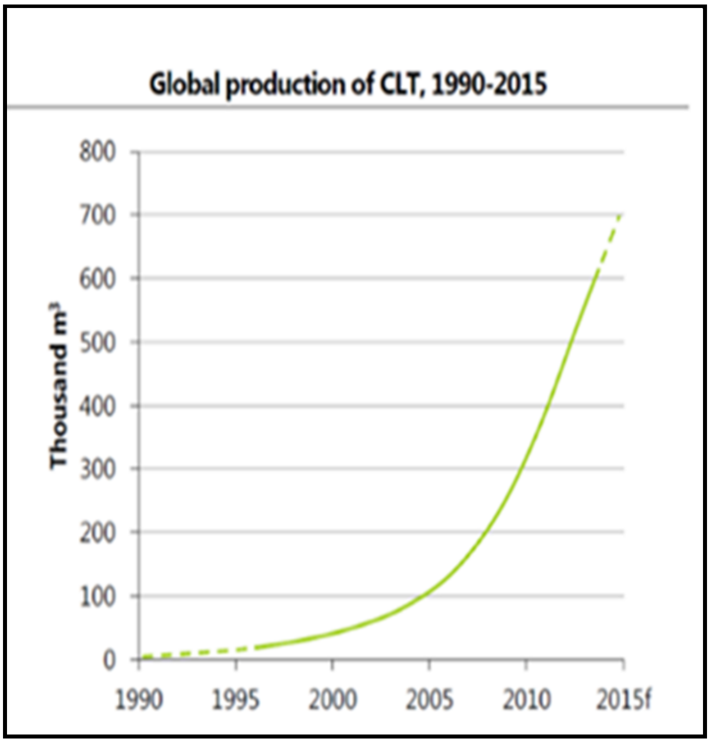


Figure 1. Rise in global production of CLT (UNECE/FAO Forest products Annual Market Review 2014-2015/Institute of Timber Engineering and Wood Technology, Graz University of Technology 2015).

However, like all wood and many other building products, EWPs can be subject to degradation caused by biological (e.g. fungal decay, moulds, borers and termites), physical (e.g. fire, corrosion of fasteners, weathering, abrasion) and chemical agents (e.g. staining and chemical decay). These degradation agents can result in widespread and large-scale damage that can be unsightly, very difficult and costly to repair and more importantly, can cause buildings and other structures to be unsafe and health hazards (Taylor *et al*., 2016).

Existing long-term durability performance knowledge of many EWPs such as cross laminated timber (CLT), other massive timber panels, parallel strand lumber (PSL), oriented strand board (OSB), laminated veneer lumber (LVL) and I-beams, is predominantly based on experiences in temperate regions such as Europe and North America. The Australian timber industry has relatively less experience in this field.

However, the significant interest in/and the increase in the use of EWPs in building systems, especially commercial and multi-residential structures in Australia elevates the importance of ensuring that these building components perform over the long-term and meet service life expectations.

Common barriers from building professionals and end-consumers considering timber-based building systems in Australia include risk of fire, structural integrity and long-term performance sustainability (including the risk of decay and insect degradation). In many cases, it is uncertainty over the long-term durability that will cause consumers to choose alternative materials to wood.

This report describes the outcomes of a study of EWP production, use and R&D in Europe and North America with a particular focus on wood treatment measures adopted to maximise EWP durability performance. The current status quo and implications for the Australian industry are also described. This work is considered essential in providing confidence for building professionals and end-consumers to choose and accept timber construction solutions compared to other non-wood options. Ultimately the benefit of this is increased market share for wood products and the associated many environmental advantages of using renewable wood products in the built environment.

Methodology

This report is based on a combination of site visits, interviews and literature reviews. Most of the study tours and interviews were undertaken with stakeholders in Europe and North America and to a lesser extent, consultation within Australia. The European countries visited included England, Austria, Switzerland, Germany, Sweden, Denmark and Norway. Both Canada and the USA were included in the North American tour.

Key stakeholders consulted are shown in Table 1.

Table 1. Key stakeholders consulted during study

Country	Organisation	Description	Person
England	EXOVA BM TRADA	Product certification, materials testing, laboratory services, calibration. Building products knowledge.	Dr. Hugh Mansfield-Williams

Country	Organisation	Description	Person
	Koppers Performance Chemicals	A global leader in wood preservation	Lee Christie, Fabio Antas, Dr. Lars Nyborg, Terry Wentworth
Austria	Holzfurschung	Forest Products R&D	Dr. Andreas Neumüller, Dr Gerhard Grüll, Dr Anton Wegscheider
	Stora Enso CLT Plant	Wood products producer and distributor (including CLT)	Matthias Lanator
	Koppers Performance Chemicals	A global leader in wood preservation	Andreas Spatz
Switzerland	Bern University of Applied Sciences	Building materials R&D. Timber engineering.	Dr Christophe Sigrist
	Blumer-Lehmann	Timber constructions, timber engineering and wood products producer	Martin Bender
	ETH	Building materials R&D. Timber engineering.	Reto Fahrni
Germany	Pollmeier	Wood products manufacturer (including LVL).	Alexandra Himsel
	University of Gottingen	Forest products R&D.	Dr Holger Militz, Sascha Bicke

Country	Organisation	Description	Person
Denmark	Koppers Performance Chemicals	A global leader in wood preservation	Dr Lars Nyborg
	Danish Technological Institute	Forest and building products R&D.	Dr Morten Klamer, Dr Thomas Venas, Soren Bang-Achton
Sweden	Koppers Performance Chemicals	A global leader in wood preservation	Marten Axén
	IKEA	Furniture	N/A
	Bergs Timber Bitus	Europe's largest wood treatment plant.	Henrik Egnell
Norway	Moelven	Wood products manufacturer and building systems provider (including glulam, plywood)	Harald Bjerke
	NIBIO	Forest and building products R&D.	Dr Lone Gobakken, Dr Gry Alfredsen, Dr Andreas Treu
	Treteknisk	Forest and building products R&D.	Dr Ulrich Hundhausen
USA	Koppers Performance Chemicals	A global leader in wood preservation	Dr Jun Zhang, Jacob McBrayer, John Virnich, Chuck Shaw, Brad Burmeister
	McFarland Cascade	Wood products manufacturer	Robert Campbell

Country	Organisation	Description	Person
		(including pressure treated glulam poles)	
	Arauco MDF Plant	Wood products manufacturer (including MDF)	Jon Jensen, Michael Shew
	Oregon State University	Forest and wood products R&D	Dr Jeff Morrell
	Freres Lumber Company	Wood products manufacturer (including veneer-based massive panels, plywood)	Tyler Freres
	Dr. Johnson	Wood products manufacturer (including CLT, glulam, glulam poles)	N/A
	Ridge Creek Industries	Wood products manufacturer (including fire retardant treated plywood, LVL)	Cliff Eason
	Great Southern Wood Preserving	Wood products manufacturer (particularly treated wood)	Steve Rom
Canada	University of British Columbia	Forest and building products R&D. Wood composite R&D.	Dr Phil Evans
	Weyerhaeuser	Wood products Manufacturer (including parallam - PSL)	Graeme Dick

Country	Organisation	Description	Person
	Forest Product Innovations	Forest products R&D.	Dr Rod Stirling, Dr Katherine Semple
Australia	Biotica	Timber Industry Consultancy	Michael Powell
	FWPA	Australian Forest Industry R&D. Mid-Rise Sector development.	Stefan Gerber
	EWPAA	Timber Industry Association; R&D	Dave Gover, Andy McNaught
	Hyne & Son	Leading wood processor and manufacturer	Geoff Stringer
	Timber Queensland (consultant)	Timber Industry Association; R&D	Colin McKenzie
	Timbers Preservers Association of Australia	Wood preservation industry group in Australia	Jack Norton
	Koppers Performance Chemicals	A global leader in wood preservation.	Elias Akle Dr Steve Crimp Chris Tzioutziouklaris Nick Livanes
	Department of Agriculture and Fisheries (DAF) Forest Products Innovation	Leading forest product R&D organisation in Australia	Dr Rob McGavin

Findings

Definition of EWPs

For the purposes of this report, Engineered Wood Products (EWPs) are defined as timber composites formed from various wood components (and sometimes non-wood components such as plastic and metals) in combination with adhesives. Wood components of EWPs consisting of sawn laminates, veneers, strands, particles, flakes or fibres are reconstituted together with adhesives, usually involving heat and/or pressure, into both structural and appearance sections. EWPs generally take the form of panels, rectangular sections and I-beams (Bolden and Greaves, 2008).

Examples of EWPs

There are many different types of EWPs which can be categorised according to the type of feedstock used in their manufacture. Common EWPs include:

Sawn - based

Glulam and Cross Laminated Timber are the dominant EWPs in this category.

Glulam (Figures 2 -4), or glued laminated timber, is an engineered wood product manufactured by gluing together pieces of timber, known as laminates (Wood Solutions, 2018). This process produces larger size and longer length members, which can be curved or straight (Wood Solutions, 2018).

Glulam has a reputation for being used in striking, exposed applications such as vaulted ceilings and other designs with soaring open spaces (APA, 2018). In homes, churches, public buildings, and other light commercial structures, glulam is often specified for its beauty as well as its strength (APA, 2018). It's also used in common hidden applications, including simple purlins, ridge beams, garage door headers, floor beams, and large cantilevered beams (APA, 2018). In commercial construction, glulam is used in applications ranging from large, flat roof systems to complex arches (APA, 2018). Glulam also meets demanding environments of bridges, utility poles, cross arms, and marinas (APA, 2018). Glulam is also sometimes reinforced with hidden steel for extra strength and rigidity.

Figure 2. Glulam Bridge (Source: Camero, 2017, The Fifth Estate, 2017).

Figure 3. Curved glulam in factory in Switzerland

Figure 4. Glulam structure in construction in Norway

Cross Laminated Timber (CLT) (Figures 5-7) is an engineered wood product, similar in construction to an extremely large plywood, used for pre-fabricated structural applications

(Wood Solutions, 2018). However, the obvious difference is that CLT uses sawn feedstock as opposed to veneers in plywood products.

Layers of timber, known as lamellas, are glued together with the grain alternating at 90-degree angles for each layer. The exterior layers' grains run lengthways, giving optimum strength (Wood Solutions, 2018).

Cross-laminating layers of wood improves the structural properties of wood by distributing the along-the-grain strength of wood in both directions, and this means that CLT panels can be used to form complete floors, walls and roofs (Wood Solutions, 2018).

Lightweight yet very strong, with superior acoustic, fire, seismic, and thermal performance, CLT is also fast and easy to install, generating almost no waste at the construction site (APA, 2018). CLT can also offer design flexibility and low environmental impacts. For these reasons, cross-laminated timber is proving to be a highly advantageous alternative to conventional materials like concrete, masonry or steel, especially in multi-residential and commercial construction (APA, 2018).

Figure 5. CLT in factory in North-West USA

Figure 6. CLT being used in building construction. (Source – Avanti Architects, 2017)

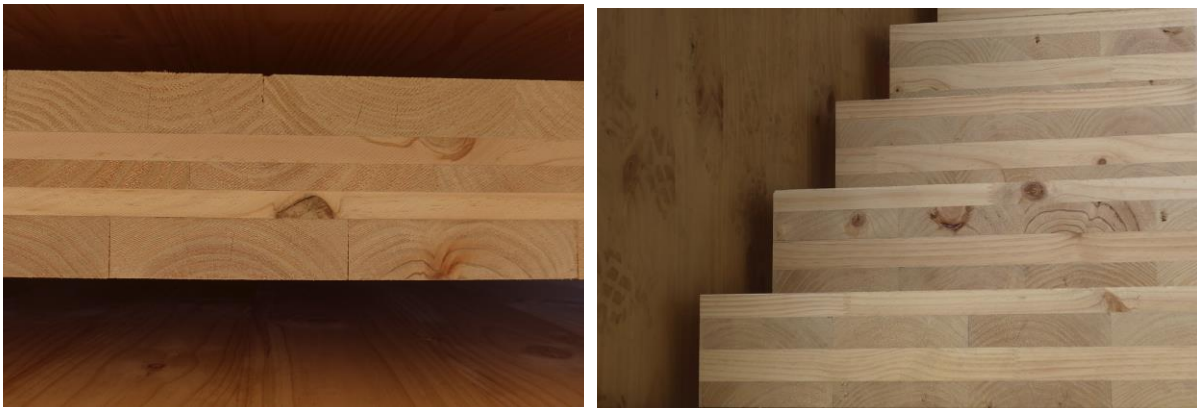


Figure 7. CLT section (L) and CLT in stairwell (R). (Source – XLAM, 2017).

Veneer-Based

Plywood and Laminated Veneer Lumber (LVL) dominate the veneer-based EWPs.

Plywood (Figure 8) is a panel product made from peeled veneer layers that are arranged perpendicular to each other and bonded by adhesive. (Leggate *et al*. 2017).

Plywood is suitable for a variety of end uses including subflooring, single-layer flooring, wall and roof sheathing, sheathing ceiling/deck, structural insulated panels, marine applications, siding, webs of wood I-joists, concrete forming, pallets, industrial containers, mezzanine decks, and furniture (APA, 2018).

Figure 8. Plywood. (Source – Big River Group, 2018)

Laminated veneer lumber (LVL) (Figure 9) is a composite of wood veneer sheet elements with wood fibres primarily oriented along the length of the member, where the veneer element thickness is typically 6.4mm or less (APA, 2018). Popular LVL applications include headers and beams, hip and valley rafters, scaffold planking, and the flange material for prefabricated wood I-joists (APA, 2018).

Figure 9. LVL used in roof structure. (Source – Wesbeam, 2018)

Multilaminar wood (MLW) (Figure 10) is made of superimposed layers of veneer which are spread with adhesives and then pressed so as to form a block from which sliced veneers or sawn pieces are obtained, mainly for decorative purposes (Hopewell *et al*., 2017). Various effects, colours, forms and patterns can be achieved by bleaching or dyeing veneers, using different glue types with varying colours, block moulding and also slicing or sawing the blocks at different angles (Hopewell *et al*., 2017).

Figure 10. Multilaminar Wood (Source – Left (Rob McGavin, 2017); Right (Ecospecifier, 2018)

Veneer-based mass panels (Figures 11 and 12) are another type of veneer-based EWP. Veneer-based mass panels provide an alternative to CLT and can be manufactured with panel sizes over 10m in length, up to 3.6m in width and typical thicknesses exceeding 170mm. Veneer-based mass panels have existed in Australia since the 1980s with the development mainly focused on bridge decks (Hopewell *et al*., 2017).

Figure 11. Veneer-based mass panels in North-West USA.

Figure 12. Section of veneer-based mass panel. (Source – Portland Business Journal, Matt Swain Photography)

Particle or Fibre Based

Particleboard, Medium Density Fibreboard (MDF) and Hardboard, mainly sold in panel form are the dominant EWPs in this category.

Particleboard (Figure 13) is a reconstituted wood panel product manufactured from wood particles. It can also be manufactured using wood flakes or strands (Wood Solutions, 2018).

Particleboard is used for different internal applications, which is dependent on the grading of the material. Common applications include furniture, veneer substrates and cupboards (Wood Solutions, 2018). Structural grade particleboard is primarily used for internal flooring but may be used for other load-bearing applications in dry conditions (Wood Solutions, 2018).

Figure 13. Particleboard (Source – Carter Holt Harvey Wood Products Australia, 2018)

Medium Density Fibreboard (MDF) is a reconstituted wood panel product. It is a dry-processed fibreboard manufactured from wood fibres, as opposed to veneers or particles, and is denser than plywood and particleboard (Wood Solutions, 2018). MDF has an even density throughout and is smooth on both sides (Wood Solutions, 2018).

MDF is reconstituted into wood panels in a variety of widths, thicknesses and lengths. Bonding is achieved by the addition of synthetic resin adhesives, which are cured under heat and pressure. Paraffin wax is added to assist with water repellency, while other chemicals can be added during manufacturing for more specific protection (Wood Solutions, 2018).

MDF is primarily used for internal use applications, in part due to its poor moisture resistance. It is available in raw form with a fine sanded surface or with decorative overlay such as wood veneer, melamine paper or vinyl (Wood Solutions, 2018).

Hardboard, also called high-density fibreboard (HDF), is similar to particle board and medium-density fibreboard but is denser, much stronger and harder because it is made out of exploded wood fibres that have been highly compressed (Wikipedia, 2018). It differs from particle board in that the bonding of the wood fibres requires no additional materials, although resin is often added (Wikipedia, 2018). It is used in construction, flooring, furniture, home appliances, automobiles and cabinetry. A wood veneer can be glued onto it to give the appearance of solid wood (Wikipedia, 2018). Other overlays include Formica, laminated papers, ceramics and vinyl. It has many uses, such as a substrate (Wikipedia, 2018).

Strand-based

Important strand-based EWPs include Oriented Strandboard (OSB), parallel strand lumber (PSL) and longitudinal strand lumber (LSL).

OSB (Figure 14) is a widely used, versatile structural wood panel. Manufactured from waterproof heat-cured adhesives and rectangularly shaped wood strands that are arranged in cross-oriented layers, OSB is an engineered wood panel that shares many of the strength and performance characteristics of plywood (APA, 2018). OSB's combination of wood and adhesives creates a strong, dimensionally stable panel that resists deflection, delamination, and warping; likewise, panels resist racking and shape distortion when subjected to demanding wind and seismic conditions (APA, 2018). Relative to their strength, OSB panels are light in weight and easy to handle and install (APA, 2018).

OSB is produced in huge, continuous mats to form a solid panel product of consistent quality with no laps, gaps, or voids. Finished panels are available in large dimensions, minimizing the number of joints that can "leak" heat and admit airborne noise (APA, 2018).

OSB is suitable for a variety of end uses including subflooring, single-layer flooring, wall and roof sheathing, sheathing ceiling/deck, structural insulated panels, webs for wood I-joists, industrial containers, mezzanine decks, and furniture (APA, 2018).

Figure 14. OSB used in house construction. (Source – IHB, 2018)

Parallel Strand Lumber (PSL) (Figures 15 and 16) is manufactured from veneers clipped into long strands laid in parallel formation and bonded together with an adhesive to form the finished structural section (APA, 2018). Like LVL and glulam, this product is used for beam and header applications where high bending strength is needed. PSL is also frequently used as load-bearing columns (APA, 2018).

Similar to PSL, laminated strand lumber (LSL) is made from flaked wood strands that have a length-to-thickness ratio of approximately 150 (APA, 2018). Combined with an adhesive, the strands are oriented and formed into a large mat or billet and pressed (APA, 2018). LSL is used in a variety of applications from studs to millwork components (APA, 2018).

Figure 15. Parallam at the University of British Columbia, Canada

Figure 16. Pressure treated Parallam Plus. (Source – Weyerhauser, 2018).

Hybrid EWPS

These EWPs are formed from a combination of feedstocks which can also include wood in combination with other materials such as plastic, glass, metal, agricultural fibres, steel and cement. Some purely wooden feedstock hybrid EWPs include veneer overlayed CLT, LVL or MDF. I-Beams are also an example of a hybrid EWP which can be made from sawn or LVL flanges with an OSB or plywood web.

I-joists (Figure 17) are strong, lightweight, "I" shaped engineered wood structural members that meet demanding performance standards (APA, 2018). I-joists are comprised of top and bottom flanges, which resist bending, united with webs, which provide outstanding shear resistance (APA, 2018). The robust combination of structural characteristics results in a versatile, economical framing member that is easy to install in residential and light commercial projects (APA, 2018).

Wood plastic composites (Figure 18) are another example of a hybrid EWP that is rapidly growing market share internationally.

Figure 17. Treated I Beams ready for dispatch.

Figure 18. Wood plastic composite decking. (Source – Zhejiang Huaxiajie Macromolecule Building Material Co., 2018)

Main Advantages of EWPs

EWPs vary considerably in form and function, however collectively some of the main advantages of these products compared to conventional solid products are they:

1. can use lower grade wood resources including small logs, defect (or feature) containing wood and short, small wood pieces. In fact, this has been one of the main drivers for EWP development – the internationally declining supplies of large, high quality logs.

2. can yield much higher recoveries and reduce waste of wood resources.

3. can be made to almost any dimensions desirable.

4. the effects of defects can be randomised throughout the product instead of concentrated at a focal point as in sawn timber

5. desirable structural and appearance properties can be 'engineered in' – for example through strategic placement of wood with particular characteristics.

6. in some circumstances, reduced production time- for e.g. hardwood veneers and fibres can be dried in minutes compared to months for sawn timber in the case of some Australian hardwoods.

7. in some situations, more uniform and effective wood preservation- particularly where the preservative is incorporated into the product assembly process – e.g. addition of preservatives directly into the glue and strand mix in OSB production.

8. Less variable and improved structural design properties and performance.

Some of the main advantages of EWPs compared to alternative building materials such as concrete and steel are:

1. natural, renewable, sustainable and reduced carbon footprint.

2. lighter-weight and greater flexibility in design and construction.

3. faster and quieter construction.

4. in certain building types - cheaper construction.

5. warmth and aesthetically pleasing with health benefits.

Durability of EWPs

Because EWPs contain wood, they are generally subject to the same degradation agents that can negatively impact solid wood. These agents include:

- decay (Figures 19 and 20), mould and staining fungi.
- insects such as termites (Figure 21) and borers (Figure 22).
- marine borers.
- bacteria.

- weathering (Figure 23) from sun, wind, rain, snow and other factors.
- fire.
- chemical (staining, chemical 'decay', corrosion of fasteners (Figure 24)).


Figure 19. Decay in EWPs L and R. (Provided by Colin MacKenzie)


Figure 20. Further examples of decay in EWPs L and R. (Provided by Colin MacKenzie)


Figure 21. Termite damage to wood. (Source – DAF, Forest Products Innovation, 2017)

Figure 22. Lyctid beetle (borer) damage to wood including larvae and frass. (Source – Doug Howick (L) and Ted Stubbersfield (R)).

Figure 23. Weathering of wood in I-Beam durability trial in OSU field site (L) and on wooden cladding in Switzerland (R)

Figure 24. Corrosion of metal fasteners in wood. (Source – Carpentry Contractor Blog (L) and Forest Products Lab, USDA Forest Service, 2015)

However, the response of EWPs to some of these degradation agents can vary from solid products such as sawn timber. This is mainly because EWPs are composed of two materials – 'wood' and 'adhesives'. Additionally, the manufacturing conditions used for some EWPs such as the heat and pressure conditions can potentially impact on product durability. Also, EWPs are characterised by different product dimensions, geometries and configurations compared to solid wood products. Some adhesives may also have a negative impact on microorganisms which can improve EWP durability.

The general durability of EWPs is dependent on both the durability of the timber components and durability of adhesives used to bond them (Bolden and Greaves, 2008). Failure of either the adhesive or wood, results in product failure (Bolden and Greaves, 2008).

The performance of EWPs can be dramatically affected by exposure to various hazards in a "normal" building environment (Bolden and Greaves, 2008). In particular, exposure to insects and/or fungi can result in significant loss of section and therefore strength (Bolden and Greaves, 2008). Prolonged exposure of EWPs to weather and moisture can result in significant degrade of product over the medium to long term (Bolden and Greaves, 2008). However, buildings properly specified, designed, constructed and maintained using EWPs can be expected to provide excellent performance over the life of the structure (Bolden and Greaves, 2008).

The wood-moisture dynamics are different in a glued product compared to a solid sawn product and this can impact on product durability. The gluelines can also present a barrier to moisture movement into the product which may improve durability. Furthermore, the adhesives in combination with the EWP configuration cause different shrink-swell behaviour of the product compared to solid products impacting on weatherability and durability. Some studies have shown improved durability of EWPs (such as plywood and LVL) compared to solid wood counterparts (Yang *et al*., 2001; Van den Bulcke *et al*., 2011).

EWPs will generally be more stable than kiln dried sawn timber because the process of gluing together multiple wood components tends to randomise and balance moisture responses (Bolden and Greaves, 2008). However, warping, bow and spring may still result in response to differential moisture content (Bolden and Greaves, 2008).

There is also some evidence to suggest that the log pre-conditioning, high temperature drying and pressing processes used in the manufacture of some EWPs, such as plywood and LVL have the potential to effect the durability with some wood species, potentially in two ways - lowering the natural durability of the wood species, probably via extractives removal (Personal Communication, Simon Dorries, 2018) or improving durability (and dimensional stability) via high temperature modification of wood (Personal Communication, Andy McNaught, 2018).

Problems with the glueline (such as delamination and splitting) are an aspect of EWP durability that obviously doesn't apply to solid wood products. Different responses of the wood and adhesives to moisture ingress and egress can result in splitting in both the gluelines and/or the wood in EWPs (Figure 25).

For this reason, it is important that the correct type of adhesive is specified for the hazard environment in which the EWP is exposed.

In a recent comprehensive analysis of 230 large-span timber structures in Europe, mainly comprised of glulam, cracking in the timber and the gluelines was identified as the major observed timber failure. (Dietsch and Winter, 2017) (Figure 26).

Figure 25. Timber weathering and cracking in glueline and timber in Glulam post. (Provided by Colin MacKenzie)

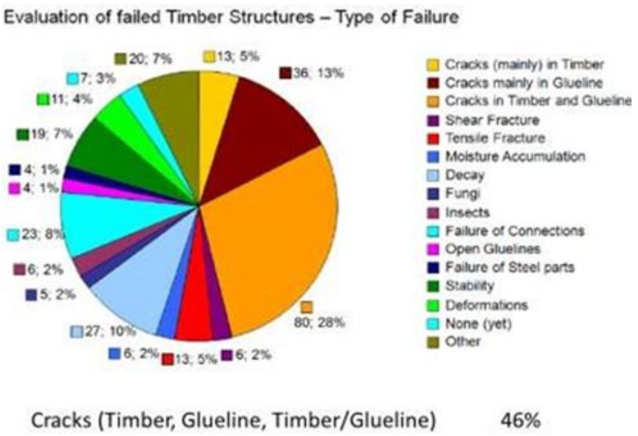


Figure 26. Evaluation of failed timber structures – Type of failure. (Source – Dietsch and Winter, 2018).

An important aspect of increasing the use of timber products in tall buildings and other structures is visual appeal. In many cases, engineered wood products (EWPs) such as glulam, cross laminated timber (CLT), plywood and laminated veneer lumber (LVL) are used in exposed applications where appearance is critically important. This is especially the case where the EWP is used in external situations such as columns, posts, beams, cladding and decking.

Surface finishes are normally used to protect EWPs against degradation caused by weathering and also to maintain aesthetic appeal over time. However, some problems are occasionally experienced with some EWPs in the marketplace, with premature failures in the surface finishes resulting in poor appearance of external EWPs in short time frames (e.g. less than 2 years). The main problems are dimensional instability, cracking, discolouration and moulds.

In Australia, where traditionally (pre-1990s) the industry had relied on highly natural durable solid hardwood, treated EWPs are a different material completely – they are composed mainly of lighter, naturally non-durable softwoods with wood preservatives often confined only to the outer layers via envelope treatments. As Geoff Stringer, Hyne Timber, describes it…… many hardwoods were naturally durable from the inside out, whereas softwood based, treated EWPs are typically durable from the outside in (Personal Communication, Geoff Stringer, 2018). Many Australian builders are still getting accustomed to this fundamental change in building material.

The Australian Building Codes Board (ABCB) defines durability as "capability to perform a function over a specified period of time" (ABCB, 2015). In this context, many factors influence the durability of wood products. This includes:

- environmental agents
- temperature
- radiation
- humidity
- rainfall
- wind
- soil type
- pollutants
- biological agents
- chemical effects, etc.

(MacKenzie *et al*. 2015)

Specific conditions that are stated when considering durability requirements include:

- condensation
- cyclic changes
- agents due to usage, e.g. abrasion, maintenance
- ground contact
- intended use
- performance criteria
- expected environmental conditions
- composition, properties and performance of materials
- structural system
- shape and detailing
- workmanship, QC, maintenance, etc

(MacKenzie *et al*. 2015)

The degradation rate and susceptibility of EWPs to decay and insect attack is directly influenced by the hazard zone where the product is located. For example, Australia is divided into various hazard zones for in-ground decay, above-ground decay, termites and corrosion. The hazard zones are mainly a function of climate, soil type and presence or absence of agents that cause degradation. Figures 27-29 shows the above-ground decay, in-ground decay and termite hazard zones for Australia.

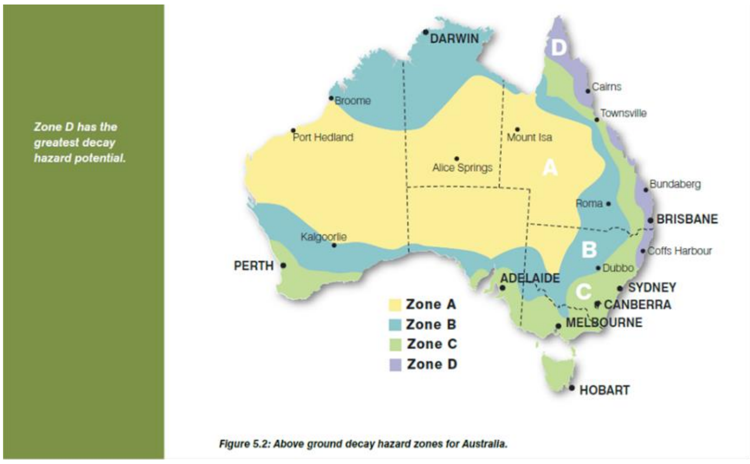


Figure 27. Above ground decay hazard zone for Australia (Source – MacKenzie et al. 2015)

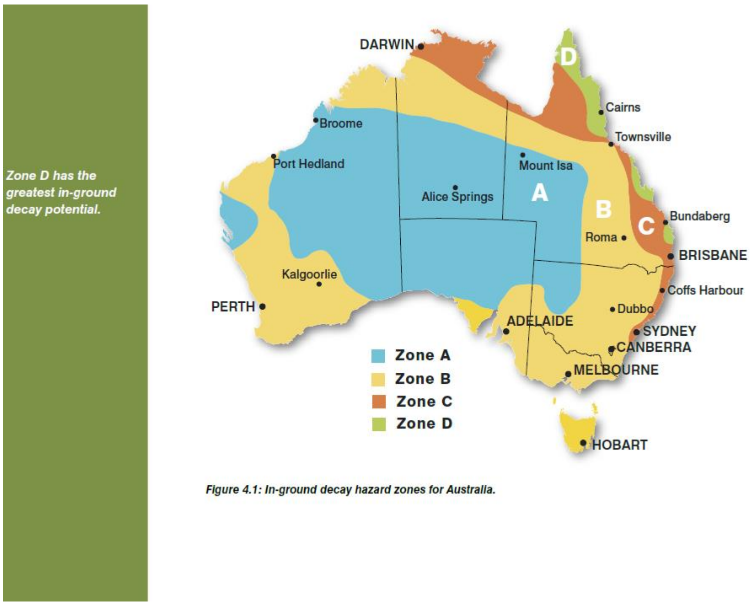


Figure 28. In-ground decay hazard zone for Australia (Source – MacKenzie et al. 2015)

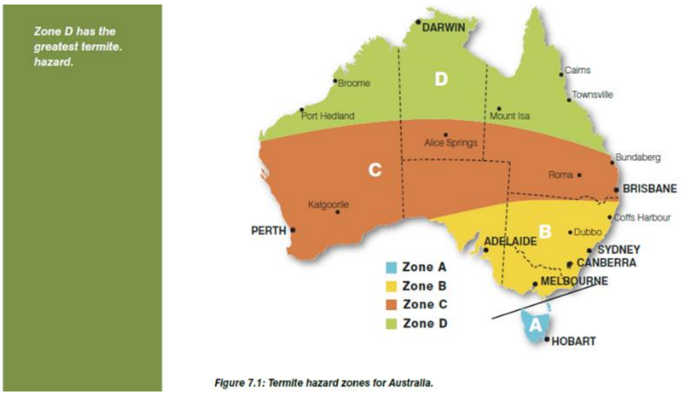


Figure 29. Termite hazard zone for Australia (Source – MacKenzie et al. 2015)

Generally, the more stable the environment the better EWPs will perform. Therefore, improved performance can be expected in inside or weather protected situations and/or with the use of protective coatings. Problems are more likely to be experienced with EWPs when in exposed applications where they are subject to rain, snow, sun, UV radiation, wind and organic debris build-up.

Maximising the durability performance of EWPs

Like all wood products, various options are typically adopted to improve durability performance of EWPs. Paramount is keeping the products dry and at a moisture content below the threshold for fungal activity (generally considered to be less than 20%). This can be achieved by appropriate product and building design, construction method, detailing, finishing, maintenance and monitoring procedures. For decay prevention, it can also be achieved by only using EWPs in covered, interior or non-exposed applications. Another option is to use naturally durable timber species in the product manufacture, however the limiting factor here is that most of the available forest resources (by wood production volumes) in Europe, North America and Australia are of low natural durability. The third option is to chemically treat the EWP or to use feedstock comprised of modified wood. A fourth option is to use combinations of all the above.

Design, construction, detailing, finishing, maintenance and monitoring practices

EWPs should be designed and installed such that the expected life span of the product exceeds the minimum required design life for the building component (Bolden and Greaves, 2008).

In many cases, protection of EWPs from degradation may just rely on appropriate design, construction, detailing, finishing, maintenance and monitoring practices without chemical and/or modification treatments. The central element of this approach is to keep the wood dry and below a moisture content suitable for fungal activity. This approach uses various means to stop the wood getting wet including direct covering, adequate drainage and ventilation. The five D s are stressed for ensuring good performance of wooden elements and structures (Beebe and Kam-Biron, 2016). These are: drainage (removal of bulk water), deflection (diversion of moisture from the wood), drying, distance (from ground or dampness) and durability (naturally durable or treated wood) (Beebe and Kam-Biron, 2016).

This approach stresses adequate architectural and structural detailing to maximise durability performance of wooden structures. The following are some key factors that should be considered:

- shielding (Figures 30 and 31) – overhangs, pergolas, vegetation, capping, flashing, fascias, barges, etc
- isolation (Figures 32 and 34) – damp proof course's, sarking, claddings, etc
- moisture traps – housed joints, free draining, well ventilated, end grain
- ventilation and condensation – cold climates, warm climates, sarking, foil, insulation, etc
- joint detailing.

(MacKenzie *et al*. 2015)

Moisture sensor strips can also be used to monitor moisture ingress into buildings.

Various measures may also be adopted to stop termite ingress into wood structures – these can include isolation, regular inspection and physical barrier measures such as concrete podiums, ant caps, mesh and chemical treatment of the soil.

Figure 30. Large overhangs provide good protection against moisture ingress into buildings (Source – Better Home Lifestyle)

Figure 31. Capping protection of glulam in roof structure (Source – i.pinimg)

Figure 32. Glulam posts isolated from ground. (Source – Trout Creek Truss)

Figure 33. Glulam foot-bridge with protective finish. (Provided by Colin MacKenzie)

Figure 34. Bituminous Damp Proof Course (DPC) fixed to top of deck joists. (Provided by Colin MacKenzie et al., 2015)

Fire protection is often achieved by enclosing the wood in fire resistant materials such as plasterboard (gyprock) and/or the use of sprinkler systems. In some cases, as with massive timber products such as CLT, fire performance may be achieved by relying on the charring characteristics of the wood.

Traditional Wood Treatment Approaches with EWPs

There are four main approaches to treating EWPs:

1. treating the wood feedstock before gluing and product assembly – e.g. treating individual veneers before gluing and assembly of plywood or LVL
2. treating the wood during the gluing and/or product assembly process e.g. glueline treatments in plywood or LVL and zinc borate incorporation at the strand blending stage in OSB production.
3. treating the EWP after manufacture – e.g. pressure treatment of glulam, plywood or LVL, or coatings applied to the surfaces of EWPs. Note that post-manufacture treatment can sometimes extend to treatments on-site – for e.g. the use of diffusible spray treatments at the construction site.
4. Combinations of 1 to 3 e.g. use of glueline treatments in combination with surface spray treatments in plywood and LVL.

The approach taken will be influenced by many factors including the requirements of relevant standards and customers, type of EWP, type of preservative and treatment application method, end-use application, costs and available equipment.

There are advantages and disadvantages with each option and also not all options are feasible with certain preservatives, glues and types of EWPs. For example, treating wood before gluing may cause problems in the gluing process and some preservatives (e.g boron containing preservatives) are sometimes not compatible with certain glues (e.g. phenolic glues) and the heat and pressure conditions in gluing processes. Another disadvantage of treatment before gluing/product manufacture is that often EWPs are planed (dressed), machined, or sanded after gluing which can remove well treated wood, expose untreated wood and also create a waste management problem. However, treatment of feedstocks before assembly will usually result in more uniformly treated wood products with greater preservative presence in the full product cross section.

Glueline treatments are currently only approved in Australia for H1 and H2 applications – therefore mainly for preventing damage caused by insects. Also, glueline treatments are currently limited only to veneers or laminates of certain thicknesses because of limits in the preservative penetration movement from gluelines. Although, it is likely that glueline treatments have not yet been adequately tested for wood thicknesses greater than those commonly used for such treatments. For this reason, glueline treatments are not currently used in sawn timber-based EWPs.

Treating the EWP post manufacture can be advantageous in terms of minimising problems in the gluing process, however in many cases post manufacture treatments of EWPs are limited to envelope treatments because of difficulties in penetrating through the gluelines. Other problems with post manufacture treatment are treatment equipment size constraints – for e.g. the difficulty presented by treatment of full size CLT panels.

For plywood and LVL – all four approaches outlined above are in use. For glulam, treatment options 1 and 3 are typically used internationally. Strand, particle or fibre-based EWPs such as OSB, particleboard and MDF are often treated by option 2, therefore preservatives such as zinc borates are added during the mixing and blending stage in what is called an integral treatment. A major advantage of strand, particle and fibre based EWPs is the possibility to achieve very uniform and complete penetration in the product. Apart from biocides, water repellents and fire retardants are also often added to these types of products in this way.

It is common to use surface treatments such as brush-on or spray-on coatings to provide temporary protection to EWPs during storage, transport and construction. These treatments usually include water repellents and fungicides to stop mould and sapstaining. In some cases, surface treatments may just be end-sealing treatments to limit moisture ingress into the wood products. Also surface treatments can include insecticides.

Finishing of EWPs is also common and essential to prevent the appearance of weathered wood surface mechanical breakdown (cracking) and to provide some protection against moisture related shrinkage and swelling (Bolden and Greaves, 2008). Finishes provide a protective vapour barrier to the surface, rather than a total moisture seal (Bolden and Greaves, 2008). The broad range of commercial finishes available for EWPs includes paints, clear finishes, water repellents and stains (Bolden and Greaves, 2008). Selection of the appropriate finish depends upon the desired appearance, cost and intended maintenance regime.

Currently, apart from the temporary surface treatments and finishes mentioned above, there appears to be minimal preservative treatment of CLT occurring worldwide. The majority of CLT installed in buildings worldwide is untreated with a reliance on building design, installation, monitoring and maintenance practices to provide long-term durability. However, there is a growing movement around the world to mandate or enforce treatment of CLT given the serious consequences of failure in multi-residential and commercial buildings. New Zealand and the UK are two regions where momentum towards CLT treatment is strong. Proponents of CLT preservative treatment refer to the possible design, building and maintenance failures that arise and lead to ‘leaky’ buildings through factors such as rainwater intrusion, exposure to weather during construction, plumbing leaks, condensation, inadequate ventilation, fire sprinkler activation. An additional concern with structurally critical EWPs such as CLT is that they are often very difficult to access and inspect during service.

Options currently being considered for CLT preservative treatments include:

- Treating all laminates before gluing and product assembly
- Treating only some laminates (e.g. surface laminates that will be more exposed to moisture and degradation agents) before gluing and product assembly.
- Surface treatments after manufacture including diffusible spray treatments – eg borate/glycol and borate rods (FPI, 2018). This can include on-site diffusible treatments.

Many of the European species used for CLT and other EWPs are not easily treated. This is a major disadvantage compared to more treatable species used in CLT manufacture such as radiata pine.

The durability of wood can be greatly augmented by the use of chemical preservatives that protect the wood from biological attack by organisms such as insects and fungi. There are numerous types of wood preservatives that vary in chemical composition, intended application or exposure environment, required chemical loading in wood, performance, treatment method (Figure 35), cost, ease of use, safety and toxicity. These usually contain insecticides and/or fungicides depending upon the intended wood product applications (Figures 36 – 39).

Common preservatives include: boron, micronized and soluble (non-micronized) copper azole (CA), alkaline or ammoniacal copper quaternary (ACQ), bifenthrin, permethrin, imidacloprid, chromated copper arsenate (CCA), azoles and light organic solvent (LOSP) based formulations. Creosote and pentachlorophenol are also still used in some countries for treating EWPs – e.g. creosote treated glulam used in bridges in Norway. There are also chemicals for enhancing fire retardancy, weathering performance, water repellency, colour and appearance. Remedial treatments of utility poles and other elements and structures are also undertaken using a variety of methods including fumigants, rods, pastes and liquid treatments. Common active ingredients for these include boron, fluoride, potassium dichromate, MITC (methylisothiocyanate) and copper napthenate.

Preservative application methods for EWPs are similar to solid wood products – therefore vacuum-only, vacuum pressure, dip, spray, diffusion, brush or roller are all potentially possible with EWPs. However, the chosen preservative and choice of application method will depend on the requirements of standards and customers, type of EWP, type of preservative, end-use application, available equipment and cost.

Preservative treatment of wood is primarily concerned with the treatment of sapwood because the heartwood of many species is difficult to treat successfully (i.e. in full compliance with standards) in a commercially viable manner with conventional methods. However, veneers, fibres, particles, strands containing heartwood are usually easier to treat compared to sawn wood with heartwood because of the smaller size and in the case of veneers, peeler checks that aid preservative penetration. This can mean that in some cases heartwood penetration can be more feasible in EWPs.

Most countries have standards that specify treatments intended to protect EWPs in service from decay organisms and insect pests. Treatment specifications vary depending on the type of wood (hardwood, softwood), its natural durability and its exposure and service requirements. For example, in Australia detailed requirements are provided in the Australian timber preservation standards (AS1604 series). In Australia, there are six main levels of treatment (hazard levels) and a number of sub-levels which relate to the durability or biological hazard to which the end product is going to be exposed. Preservative treatment level is specified using the hazard level scale. (Table 2).

Table 2. Levels of treatment – Hazard Levels in Australia. (Source – The Australian Timber Database)

Hazard Level	Exposure	Specific Service Conditions	Biological Hazard	Typical Uses
H1	Weather protected, above ground	Completely protected from the weather and well ventilated and protected from termites	Lyctid borer	Framing, flooring, furniture, interior joinery
H2	Weather protected, above ground	Protected from wetting, Nil leaching	Borers and termites	Framing, flooring, etc., used in dry situations
H2F	Weather protected, above ground	Protected from wetting, Nil leaching	Borers and termites	Framing (envelope treatment) used in dry situations south of the Tropic of Capricorn only
H2S	Weather protected, above ground	Protected from wetting, Nil leaching	Borers and termites	LVL/Plywood (glue-line treatment) used in dry situations south of the Tropic of Capricorn only
H3	Weather exposed, above ground	Subject to periodic moderate wetting and leaching	Moderate decay, borers and termites	Weatherboard, fascia, pergola posts (above ground), window joinery, framing and decking
H3A	Weather exposed, above ground	Products predominantly in vertical exposed situations and intended to have the supplementary paint coat system that is regularly maintained	Moderate decay, borers and termites	Fascia, bargeboards, exterior cladding, window joinery, door joinery and non-laminated verandah posts
H4	Weather exposed, in-ground contact	Subject to severe wetting and leaching	Severe decay, borers and termites	Fence posts, greenhouses, pergola posts (in-ground) and landscaping timbers
H5	Weather exposed, in-ground contact, contact with or in fresh water	Subject to extreme wetting and leaching and/or where the critical use requires a higher degree of protection	Very severe decay, borers and termites	Retaining walls, piling, house stumps, building poles, cooling tower fill
H6	Marine waters	Subject to prolonged immersion in sea water	Marine wood borers and decay	Boat hulls, marine piles, jetty cross bracing

Figure 35. Wood preservation plant

Figure 36. Treated I-Beams

Figure 37. Pentachlorophenol treated glulam in bridge

Figure 38. Treated timber framing

Figure 39. Treated particleboard flooring

Novel Treatment Methods

Novel or non-traditional preservation methods include wood modification by heat treatment (Figure 40), chemical reactions (e.g. acetylation (Figure 41)), polymerisation and impregnation (e.g. furfurylation, silicon). These methods are much less commonly used compared with traditional chemical preservative options and are normally more expensive; however growing restrictions on biocides and recent technological advances are resulting in their increased uptake. Motivated by health and environmental concerns, the general strategy with wood modification is to increase the durability of wood without the use of toxic compounds. Most of these methods rely on modification of the wood structure and/or chemistry, so that water movement into the wood is limited, and also the wood becomes less attractive to decay organisms.

Currently, world-wide, there is very minimal use of modified wood in EWPs. Their use seems to be mainly confined to solid wood products. However, even for solid wood products worldwide, market share of modified wood is currently estimated to be less than 3% (opinion of numerous stakeholders consulted during this study).

Another area of R&D in the non-traditional wood treatment area is the impregnation or incorporation of extractive compounds from the heartwood of naturally durable species such as cypress pine (*Callitris glaucophylla*) into non-durable sapwood. In the past, this approach hasn't been commercially viable. However, another approach currently being trialled by the DAF Forest Product Innovations group in Queensland is the combination of naturally durable wood such as cypress pine with non-durable wood such as hoop pine (*Araucaria cunninghamii*) in EWPs such as plywood.

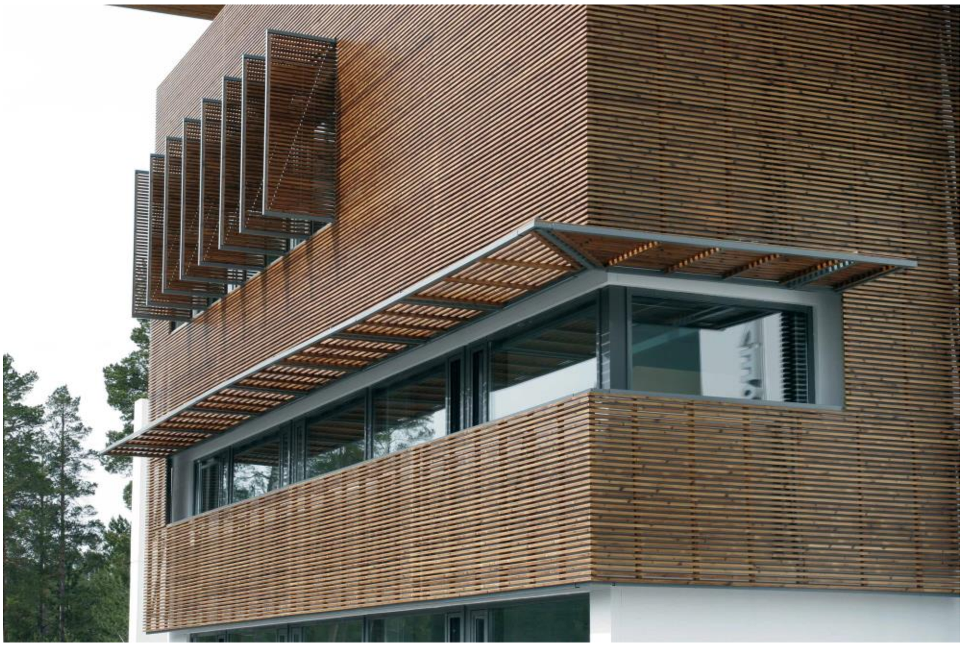


Figure 40. Thermowood screened building. (Source – Corell Timber)

Figure 41. Tricoya treated MDF in sheep on right showing improved exterior performance after outdoor exposure at the University of British Columbia.

North America

General forest industry

The USA has 310 M hectares of forests (FAO, 2015 (b)) (Figure 42) and 9% of the world's certified forests (Natural Resources Canada, 2017). The USA is the world's leading producer of industrial roundwood (368.6 M m^3 per annum; FAO, 2015 (a)) and sawn timber (76.9 M m^3

per annum; FAO, 2015 (a)) and the world's second largest producer of wood-based panels (33.8 M m^3 per annum; FAO, 2015 (a)). In the USA, the most important softwood resources are the Southern pines (*Pinus spp*.), Douglas fir (*Pseudotsuga menziesii*), ponderosa pine (*Pinus ponderosa*), western hemlock (*Tsuga heterophylla*) and lodgepole pine (*Pinus contorta*) (FAO,2015(b)). Important hardwoods include red maple (*Acer rubrum*), white oak (*Quercus alba*), yellow poplar (*Liriodendron tulipifera*), northern red oak (*Quercus rubra*) and sugar maple (*Acer saccharum*) (FAO, 2015 (b)).

In 2016, forestry and logging contributed US$20.96 B as gross output to the US GDP (BEA, 2018). The contribution of the wood products sector as gross output was US$104.3 B in 2016 (BEA, 2018).

Canada, with 347 M hectares of forest has one of the World's largest area of forest, more than the USA and China. (Natural Resources Canada, 2017). 37 % of the worlds certified forests are in Canada. (Natural Resources Canada, 2017). In 2016, the forest industry contributed $23.1 B to Canada's GDP (Natural Resources Canada, 2017). The Canadian wood products industry is dominated by softwood production including various spruce species (*Picea spp*.), hemlock (*Tsuga spp.)*, Douglas Fir (*Pseudotsuga menziesii*), lodgepole pine (*Pinus contorta*), jack pine (*Pinus banksiana*), western red cedar (*Thuga plicata*), larch (*Larix spp.)* and fir (*Abies spp*.) (FAO Country Report, 2015). Important hardwood species include aspen (*Populus spp*.), cottonwood (*Populus spp*.), poplar (*Populus spp*.), maple (*Acer spp*.), birch (*Betula spp*.) (FAO, 2015 (c)).

Canada's total standing wood volume is 47 billion m^3. In 2015, around 161 M m^3 of industrial round wood was harvested from these forests (Natural Resources Canada, 2017). British Columbia accounted for nearly half (42%) of Canada's industrial roundwood harvest followed by Alberta and Quebec (Natural Resources Canada, 2017). Canada is the fourth largest producer of industrial roundwood, the third largest producer of sawnwood (47.1 M m^3 per annum; FAO, 2015) and the fourth largest producer of wood-based panels (12.8 M m^3 per annum; FAO, 2015).

Figure 42. Forests near Oregon, USA

EWP and wood treatment sector

As per the situation with Europe, most EWPs in use in both the USA and Canada are not preservative treated. Most EWPs are used internally or in covered situations with a reliance on adequate building design, construction, detailing, finishing, maintenance and monitoring practices to provide durability performance. The wood preservative treatment industry in both the USA and Canada is mainly solid wood product based.

In the USA and Canada, with the exception of the southern states of the USA and Hawaii, there is minimal termite risk, therefore there is reduced incentive for insecticidal treatments as in Australia for framing.

In most cases, EWPs are treated only if they are being used in exposed, hazardous and structurally critical applications (e.g. glulam utility poles, bridge members) or exported to places demanding treatment for some applications, such as Australia. Therefore, in the North West USA there is treatment of LVL (mainly Douglas fir) with glueline insecticides for sale in the Australian market.

Hawaii is a notable exception with building codes requiring treatment of all wood construction materials, including EWPs.

Compared to Europe, there is much less sensitivity towards biocide use in the USA and Canada and still widespread use of traditional preservatives such as CCA, creosote and pentachlorophenol. The dominant preservatives in use are waterborne treatments such as micronized copper azole, soluble copper azole, ACQ and micronized copper quaternary compounds and boron. As per the situation in Europe and compared to Australia, there is also a greater focus on the appearance of exposed treated and un-treated wood. As a result of this many products are in the marketplace that enhance the appearance of wood including water repellents, colorants, coatings and finishes. These are mainly used in applications such as cladding, fencing and decking.

LOSP treatments are not commonly used in the USA or Canada. This is mainly due to the volatile organic compound (VOC) restrictions, undesirable odour and high costs. Additionally, in the USA and Canada, unlike Australia, for most applications, there is generally less requirement to re-dry wood after treatment which means less incentive to use treatments such as LOSP that do not require post treatment drying.

There was no evidence of CLT treatment with biocides in Canada or the USA. Parallam (PSL) is being pressure treated in Canada by Weyerhaeuser. Freres Lumber is investigating preservative treatment options for veneer-based massive panels, particularly for export to places such as Hawaii and Australia. In some cases, OSB is being treated with zinc borate. Mainly for commercial construction applications, plywood and LVL are treated with CCA and other preservatives. Glulam is being pressure treated in Canada and the USA with pentachlorophenol and creosote. Pressure treated glulam applications include glue laminated poles used in the North American utility pole sector (Figures 43 and 44).

Figure 43. Installation of glue laminated utility pole (Source – New Jersey Business Systems, Inc.)

Figure 44. Glue laminated utility pole. (Source – Rauckman High Voltage Sales, LLC)

In Canada, poles, railway ties (sleepers) and large industrial timbers are commonly treated with CCA, pentachlorophenol or creosote. Also, railway ties in North America are sometimes treated with dual treatments of boron and CCA.

Refractory (difficult to treat) wood is a big problem in NW USA and Canada with some species such as Douglas fir and therefore often incising is used to enhance penetration (Figure 45). Additionally, some water-based treatments include penetration enhancing additives specially designed for these refractory timbers.

Figure 45. Incised and treated wood in North-West USA.

Other common preservative treatments in the USA and Canada are remedial treatments for utility poles.

As per the situation in Europe, there is common use of brush-on or spray-on water repellents and other coatings to protect EWPs against moisture and mould problems during transport, storage and construction.

Fire retardant pressure treatments (Figures 46 and 47) are being used in the USA and Canada for EWP products such as plywood, LVL and Glulam. In the USA, this is mainly driven by the building codes for applications such as commercial constructions, hotels, apartments and multi-storey buildings.

Figure 46. Fire retardant treatment plant in the USA

Figure 47. Fire retardant treated plywood in the USA

Figure 48. Plastic wrapped glulam in the USA.

R&D

Three forest product research organisations in North America were visited and this section summarises the EWP durability and treatment R&D program.

The Oregon State University (OSU) (Figure 49) has several EWP durability projects underway looking at wetting rates and decay effects on LVL, Parallam, CLT and I joists. OSU is also in the process of renewing their R&D on supercritical fluid treatments.

Forest Product Innovations (FPI) (Figure 50) in Canada are working on the following EWP durability projects:

- Development of mass timber products from fire-retardant treated lamina.
- Utilization of through-treated (complete cross-section treated) thin sapwood boards as laminate stock.
- Development of fire retardant OSB for panels and webstock.

FPI has also just completed some work looking at bioincising as a means of improving preservative penetration into wood.

The University of British Columbia (UBC) (Figure 50) is also very prominent in wood composite durability R&D, particularly in the following areas:

- effect of moisture induced thickness swelling on microstructure of OSB.
- effects of adhesive z connections on the properties of a model wood composite.
- the distribution of zinc borate in composites including OSB and wood plastic composites.
- fire protection of wood composites.

OSU, FPI and the UBC are very active in coatings research. At UBC this includes investigations into plasma treatments for wood.

Many of the R&D organisations in North America undertake laboratory and field-based testing of the durability of wood products (including EWPs and also modified wood) and the efficacy of different preservatives and wood treatments. They are also involved in developing and supporting Codes and standards.

Figure 49. Glulam and LVL durability trials at OSU

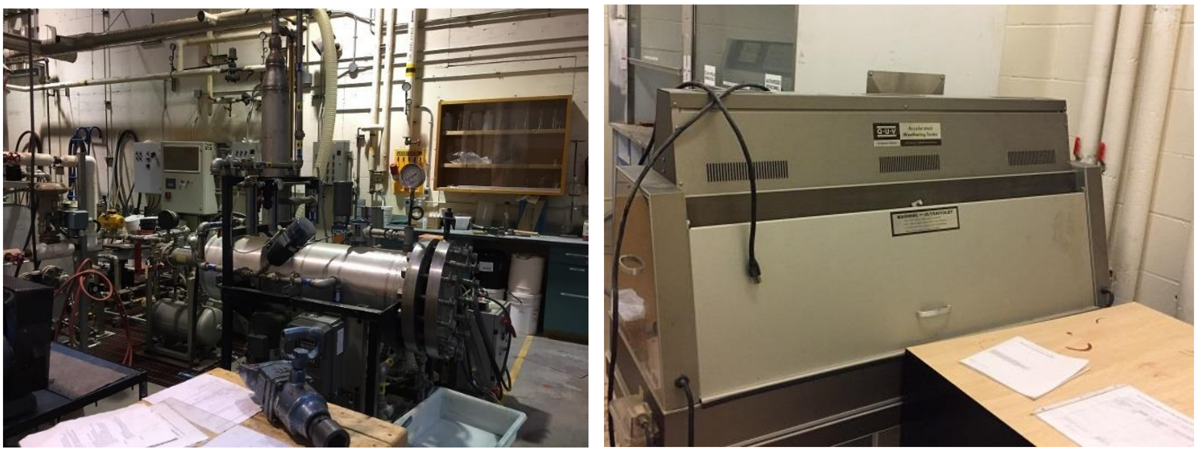


Figure 50. Experimental treatment plant at FPI (L). Weatherometer at UBC.

Figure 51. Weathering and colorant trials at KPC, USA

Particular issues

The following were particular EWP durability issues that were mentioned by stakeholders visited during the study tour:

- A problem with the performance of coatings and other finishes for wood products when used in outdoors/ exposed applications where appearance matters. Currently, this is a universal problem for the international wood products industry with most products only functioning for short timeframes and requiring extensive and regular maintenance.
- Some stakeholders expressed some concern over the fire performance of the adhesives used in EWPs. It has been suggested that most current R&D is focused only on the fire performance of the wood in EWPs rather than the fire-performance of the adhesives.

Europe

General forest industry

Table 3 outlines some key forest data for European countries.

Table 3. Key Forest Data for European countries (Source – Eurostat)

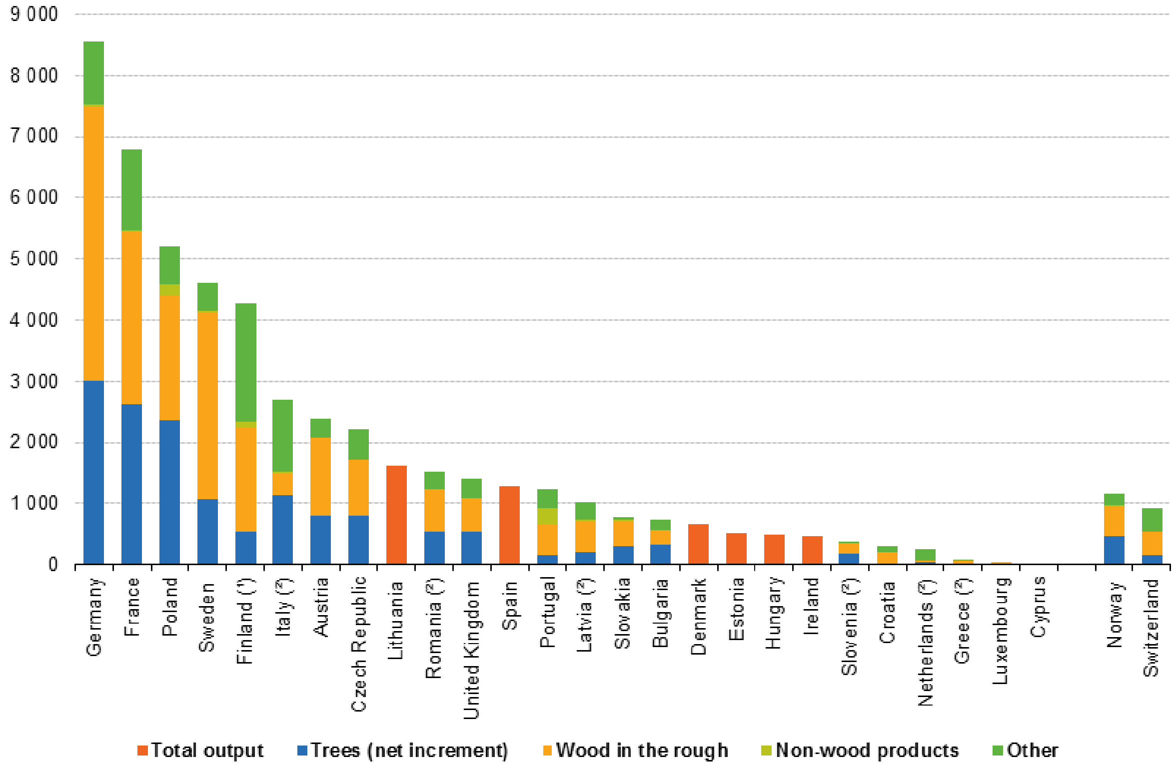
	Land area 2015 without inland water (¹)	Forest and other wooded land 2015	Forest 2015	Forest available for wood supply 2015	Forest ownership 2010	
					Public	Private (²)
	(1 000 hectares)				(%)	
EU-28	*424 694*	*181 918*	*161 082*	*134 486*	*39.7*	*60.3*
Belgium	3 033	719	683	670	46.5	53.5
Bulgaria	10 840	3 845	3 823	2 213	87.9	12.1
Czech Republic	7 722	2 667	2 667	2 301	76.6	23.4
Denmark	*4 292*	658	612	572	23.7	76.3
Germany	*34 877*	11 419	11 419	10 888	52.0	48.0
Estonia	4 343	2 456	2 232	1 994	41.3	58.7
Ireland	6 839	801	754	632	53.2	46.8
Greece	13 082	6 539	3 903	3 595	77.5	22.5
Spain	50 229	27 627	18 418	14 711	29.2	70.8
France	*55 010*	17 579	16 989	16 018	24.7	75.3
Croatia	5 659	2 491	1 922	1 740	71.7	28.3
Italy	29 511	11 110	9 297	8 216	33.6	66.4
Cyprus	921	386	173	41	68.8	31.2
Latvia	6 221	3 468	3 356	3 151	52.3	47.7
Lithuania	6 265	2 284	2 180	1 924	61.4	38.6
Luxembourg	259	88	87	86	47.1	52.9
Hungary	*8 961*	2 190	2 069	1 779	57.6	42.4
Malta	32	0	0	:	:	:
Netherlands	3 369	376	376	301	48.5	51.5
Austria	8 241	4 022	3 869	3 339	25.8	74.2
Poland	30 619	9 435	9 435	8 234	81.9	18.1
Portugal	*9 068*	4 907	3 182	2 088	3.0	97.0
Romania	23 008	6 951	6 861	4 627	67.0	33.0
Slovenia	2 014	1 271	1 248	1 139	25.3	74.7
Slovakia	*4 904*	1 940	1 940	1 785	50.2	49.8
Finland	30 389	23 019	22 218	19 465	30.4	69.6
Sweden	40 734	30 505	28 073	19 832	24.3	75.7
United Kingdom	24 251	3 164	3 144	3 144	28.4	71.6
Iceland	10 024	193	49	26	33.3	66.7
Liechtenstein	16	7	6	4	85.7	14.3
Norway	30 423	14 124	12 112	8 259	12.3	87.7
Switzerland	3 999	1 324	1 254	1 208	86.1	13.9
Montenegro	*1 345*	964	827	675	52.4	47.6
Former Yugoslav Republic of Macedonia	2 491	1 131	988	804	91.6	8.4
Serbia	*8 746*	3 228	2 720	:	50.9	49.1
Turkey	76 960	21 862	11 943	8 183	99.9	0.1

(¹) Latest available year; France: only covers the mainland.
(²) Includes any other form of ownership.
Source: Eurostat (online data code: demo_r_d3area; for_area); Food and Agriculture Organization of the United Nations:
— Global Forest Resources Assessment, 2015
— Forest Europe 2015, as published on UNECE database (http://w3.unece.org/PXWeb2015/pxweb/en/STAT/STAT__26-TMSTAT1/)

In 2015, EU-28 had close to 182 M hectares of forests and other wooded land, corresponding to around 43 % of its total area (Eurostat, 2018). The European Union (EU) accounts for approximately 5 % of the world's forests and contrary to what is happening in many other parts of the world, the forested area of the EU is slowly increasing (Eurostat, 2018).

Sweden reported the largest wooded area in 2015 (30.5 M hectares), followed by Spain (27.6 M hectares), Finland (23.0 M hectares), France (17.6 M hectares), Germany (11.4 M hectares) and Italy (11.1 M hectares) (Eurostat, 2018).

Figure 52 shows the output (million EUR) by forestry and logging per type for European countries in 2014.



(¹) 2013 data used instead of 2014
(²) 2012 data used instead of 2014
(³) 2013 data used instead of 2014

Source: Eurostat (online data codes: for_sup_cp)

Figure 52. The output (million EUR) by forestry and logging per type for European countries in 2014. (Source – Eurostat)

Tables 4 and 5 show the roundwood and sawnwood production in European countries in 2015

Table 4. Roundwood production in European countries in 2015 (Source – Eurostat)

	Roundwood production		
	Total	Fuelwood	Industrial roundwood
	(1 000 m³ under bark)		
EU-28	*446 819*	*97 745*	*349 074*
Belgium	:	:	:
Bulgaria	6 372	2 848	3 524
Czech Republic	16 163	2 336	13 827
Denmark (¹)	3 180	1 950	1 230
Germany	55 613	10 494	45 119
Estonia	7 736	2 179	5 558
Ireland	2 908	203	2 705
Greece (¹)	1 217	894	323
Spain	16 719	3 709	13 010
France	51 005	25 962	25 043
Croatia	5 178	1 769	3 410
Italy	5 052	3 004	2 048
Cyprus	11	7	3
Latvia	12 294	1 200	11 094
Lithuania	6 414	2 110	4 304
Luxembourg	381	70	311
Hungary	:	:	:
Malta (¹)	0	0	0
Netherlands	1 173	357	816
Austria	17 550	4 979	12 570
Poland	41 375	5 152	36 223
Portugal	11 533	600	10 933
Romania	*15 315*	*5 079*	*10 235*
Slovenia	5 054	1 242	3 812
Slovakia	8 995	560	8 435
Finland	59 411	7 964	51 446
Sweden	74 300	7 000	67 300
United Kingdom	10 550	1 921	8 629
Liechtenstein	8	4	4
Norway	11 876	1 718	10 159
Switzerland	4 357	1 584	2 772
Montenegro (¹)	915	707	208
FYR of Macedonia (¹)	691	577	114
Turkey (¹)	22 835	4 300	18 535

(¹) 2014 data used instead of 2015

Table 5. Sawnwood production in European countries in 2015 (Source – Eurostat)

	2000	2005	2010	2011	2012	2013	2014	2015
EU-28	100 706	108 706	100 815	101 994	100 058	99 695	102 288	102 890
EA	61 337	66 777	59 673	60 627	57 947	57 644	57 253	57 035
Belgium	1 150	1 285	1 383	1 388	1 342	:	:	:
Bulgaria	312	569	554	728	698	803	838	908
Czech Republic	4 106	4 003	4 744	4 454	4 259	4 037	3 861	4 150
Denmark	364	196	448	372	:	358	358	:
Germany	16 340	21 931	22 059	22 628	21 081	21 459	21 772	21 490
Estonia	1 436	2 063	1 771	1 503	1 491	1 558	1 554	1 650
Ireland	888	1 015	772	761	782	825	907	905
Greece	123	191	118	106	:	109	108	:
Spain	3 760	3 660	2 038	2 162	1 971	2 047	2 245	2 453
France	10 536	9 715	8 316	8 675	8 067	7 901	7 697	7 514
Croatia	642	624	677	754	851	1 192	1 294	1 488
Italy	1 630	1 590	1 200	1 250	1 370	1 360	1 430	1 470
Cyprus	9	4	4	3	3	2	2	2
Latvia	3 900	4 227	3 150	3 432	3 316	3 367	3 657	3 479
Lithuania	1 300	1 445	1 272	1 260	1 150	1 120	1 345	1 248
Luxembourg	133	133	94	78	:	:	:	:
Hungary	291	215	133	:	302	109	121	:
Malta	0	0	0	0	0	0	0	:
Netherlands	389	279	231	238	1 430	216	228	185
Austria	10 390	11 074	9 603	9 636	8 952	8 534	8 460	8 807
Poland	4 262	3 360	4 220	4 422	4 249	4 321	4 725	4 835
Portugal	1 427	1 010	1 045	1 044	1 097	854	1 035	1 134
Romania	3 396	4 321	4 323	4 442	5 500	5 532	6 019	5 936
Slovenia	439	527	760	703	660	660	700	725
Slovakia	1 265	2 621	2 576	2 204	1 430	1 430	1 750	1 600
Finland	13 420	12 269	9 473	9 750	9 440	10 440	10 920	10 640
Sweden	16 176	17 600	16 750	16 500	16 492	16 074	17 500	18 174
United Kingdom	2 622	2 780	3 101	3 279	3 409	3 581	3 764	3 493
Iceland	0	0	:	:	0	:	:	:
Liechtenstein	:	:	4	8	:	0	0	:
Norway	2 280	2 326	2 118	2 271	2 289	2 206	2 407	2 444
Switzerland	1 625	1 591	1 457	1 313	1 135	1 044	1 140	1 122
Montenegro	:	:	52	58	53	53	53	:
FYR of Macedonia	36	18	5	3	8	4	4	:
Turkey	5 528	6 445	6 243	6 461	6 682	6 405	6 635	:
Brazil	21 300	23 557	17 452	16 201	15 167	15 397	15 397	:
Canada	50 465	60 187	38 667	38 880	40 564	42 813	43 351	:
China	6 675	17 960	37 231	44 638	55 740	63 040	68 440	:
India	7 900	14 789	6 889	6 889	6 889	6 889	6 889	:
Indonesia	6 500	4 330	4 169	4 169	4 169	4 169	4 169	:
Russia	20 000	23 913	28 870	31 215	32 230	33 500	33 900	:
United States	91 076	97 020	60 013	63 174	67 474	71 115	74 803	:

Note: Data not available have been estimated by Eurostat for the purpose of caclulating EU-28 aggregates.
(:) Data not available

This data highlights the dominance of Sweden, Finland, Germany, Poland, France, Austria, Spain, Czech Republic and Latvia in European Union wood production (roundwood and sawnwood). Figure 53 illustrates that the majority of the annual roundwood production from Europe is softwood (coniferous) – around 70%. The most important softwood species for commercial wood production in Europe are Norway spruce (*Picea abies*), Sitka spruce (*Picea sitchensis*), Scots pine (*Pinus sylvestris*), Larch (*Larix spp.*) and silver fir (*Abies alba*). Important hardwood species include beech (*Fagus sylvatica*), birch (*Betula spp.*), oak (*Quercus spp.*), ash (*Fraxinus excelsior*), maple (*Acer spp.*), cherry (*Cerasus avicum*).

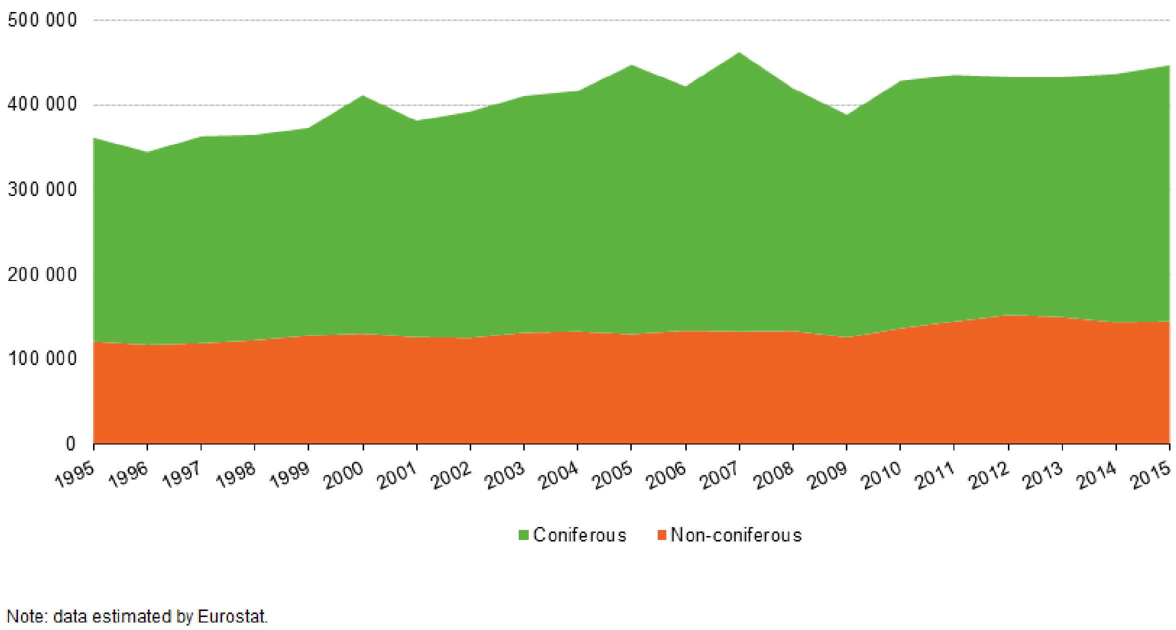


Figure 53. Annual production of roundwood in European Union countries (Eurostat)

EWP and wood treatment sector

The majority of EWPs in use in Europe are used internally or in weather protected, covered situations and are not preservative treated. The wood preservative treatment industry is mainly focused on solid wood products treatment not EWP treatment.

In general, the main biological degradation problem is from decay and to some lesser extent termites and borers. Termites weren't considered a problem in the countries visited, although they are in Southern Europe. However, problems due to termites and borers (particularly long horn house beetle) are reportedly increasing in Europe due to changing weather conditions linked to climate change (Personal Communication, Lee Christie, 2018). Recent work by the Biocomposite Centre, Bangor University has also highlighted the significantly increased decay hazard linked to a changing climate in the UK and stressed the increasing importance of wood protection research (Curling and Ormondroyd, 2018).

However, there are increasing concerns over the long-term durability performance (particularly decay) of EWPs such as CLT particularly in high occupancy buildings. In the UK, construction warranty and insurance organisations are increasingly calling for CLT to be preservative treated in the future to protect it from deterioration even if used in completely protected interior applications.

In more hazardous and structurally critical uses of wood such as bridges, then EWPs such as glulam are being preservative treated – for example, the dual treatment of glulam with copper azole and creosote for bridges in Norway.

Many of the European woods are very refractory to preservative treatment due to a high proportion of heartwood. However, in many cases according to the European standards, only the sapwood needs to be treated, which means that many of the European woods can be treated satisfactorily for end-use in Europe.

The main preservatives in use in Europe include copper and co-biocides such copper azole (micronized and soluble) and ACQ. Microemulsions of azoles are also in use. Boron is still used as a co-biocide and also as an independent treatment. LOSP treatments are not commonly used with the exception of joinery and windows. This is because of many reasons including the volatile organic compound restrictions, undesirable odour and high costs (possibly increased cost due to the regulations and restrictions). An additional reason is that in Europe, unlike Australia, for most applications, there is generally less requirement to re-dry wood after treatment which means less incentive to use treatments such as LOSP that do not require post treatment drying. Mouldicides and water repellents are also common preservatives in Europe.

In Europe, compared to Australia, there is a greater focus on the appearance of wood products in outdoor exposed situations and consequently many coatings, water repellents and finishes are being used on products such as fencing, decking and cladding. In some cases, products such as Aquatan (Koppers Performance Chemicals) are used as decorative finishes to colour the wood and do not contain any biocides.

In Europe, there is heightened sensitivity towards biocides and use is highly regulated by the Biocidal Products Regulation (BPR). A major problem for the European treatment industry is existing or pending restrictions and/or bans on the use of traditional biocides such as boron, creosote, cyproconazole and other azoles. This is a serious issue that could limit options for EWP treatment and therefore utilisation in the future. For this and other reasons, wood protection research in Europe is focused mainly on non-biocidal treatments such as modified wood. Work is also very advanced on the introduction of a creosote replacement product for those countries with existing or pending restrictions on creosote.

Fire retardant impregnation treatments do not seem to be used in a widespread manner for wood in Europe, however there is use of fire retardants for wood products in the UK for temporary protection during construction. Apparently, this has occurred because of a number of fires that have occurred during the construction phase.

There is widespread use of water repellents and other coatings which are applied to the EWPs at the manufacturing site to protect them during transport, storage and construction from moisture and moulds. In some cases, these are brushed-on or spray-on treatments.

There are many new developments in tall timber buildings in Europe which incorporate EWPs such as glulam, CLT and LVL. From observations and discussions during the field tour, very little if any of these products are being preservative treated. There is a general preference not to use chemical treatments and instead to rely on adequate design, construction, detailing, finishing, maintenance and monitoring practices. However, as mentioned above, increasing concerns regarding possible timber failures and catastrophic consequences could mean that in the near future, timber treatments (chemical and/or wood modification) may be mandated and/or demanded by consumers.

Figure 54. Beech logs used for LVL production in Germany

Figure 55. Stockpiles of spruce logs at a sawmill in Austria

Figure 56. Applying moisture repellent to glulam in a Norway factory.

R&D

As mentioned above, a major problem for the European treatment industry is existing or pending restrictions and/or bans on the use of traditional biocides. This is a serious issue that could limit options for EWP and non-EWP treatment and utilisation in the future. For this and other reasons, wood protection research in Europe seems to be increasingly focused on non-biocidal treatments such as modified wood – including impregnations of phenol resin, acetylation, furfuylation, heavy water, silica, DMDHEU, heat treatments (and in combination with other options).

Many research organisations in Europe are also focused on coatings and other finishes to improve the appearance of wood products in outdoor exposed applications.

Given that creosote will soon be banned in most European countries, work is very advanced on the introduction of a creosote replacement product.

Other areas of wood treatment R&D include enzymatic treatments and bioincising to improve wood permeability and treatability.

Many of the R&D organisations also undertake laboratory and field-based testing of wood product durability (including EWPs and also modified wood) and also efficacy trials of wood preservatives. In Europe, given heightened biocide sensitivity, many of these trials study in detail the leaching aspects of wood preservatives.

Figure 57. Leaching assessments at Holzforschung, Austria

Figure 58. Fire tests on CLT at ETH, Switzerland

Figure 59. Weathering and leaching assessments at DTI, Denmark

Particular issues

There are also some concerns in Europe regarding the effects of wood treatments on the structural properties of the EWPs – in particular, concerns regarding both short and long-term effects of the preservative on the adhesives and concerns over delamination; short and long-term fire performance of the adhesives; ageing effects on the integrity of fire retardants and preservatives; effects of the treatment process on the structural properties of EWPs.

EWP producers recognise the potential to greatly expand their market-share if more optimal and affordable wood protection options can be found.

Australia

EWP and wood treatment sector

Australia has some of the harshest wood durability hazards worldwide. This is mainly a function of the climate and also heightened termite activity. Additionally, the very large areas and wide variation in climate and other durability hazard conditions presents a formidable challenge for the performance of biological materials such as wood (Greaves, 1984). As per practices in Europe and North America, a combination of methods is used to maximise wood durability performance including:

- appropriate design, construction, detailing, finishing, monitoring and maintenance
- use of preservative treated, modified and naturally durable wood.

Some key differences in wood treatment between Australia and many other countries is the much greater use of LOSP-based treatments and also treatment of framing timber with insecticides as a prevention against termites. However, like North America and Europe, the Australian wood preservative treatment industry is mainly based on solid wood product treatment rather than EWPs.

Important wood preservatives in use in Australia include chromated copper arsenate (CCA), ammonia copper quaternary compound (ACQ), micronized and soluble (non-micronized) copper azole, bifenthrin, permethrin, imidacloprid, boron, tebuconazole, propiconazole and creosote. There are other products on the market such as water repellents, anti-sapstain and anti-moulds. There are also many coatings, finishes and paints available. Fire retardants are not used commonly for wood products in Australia, instead other measures are adopted such as relying on fire-proof plasterboard (gyprock) and/or sprinklers. Remedial treatments are also used for utility poles, bridges and other structures.

In Australia, there are six main levels of treatment (hazard levels) and a number of sub-levels which relate to the durability or biological hazard to which the end product is going to be exposed. Preservative treatment level is specified using the hazard level scale. Detailed treatment requirements are provided in the Australian timber preservation standards (AS1604 series). These standards include requirements for treatment of EWPs.

Table 6 summarizes treatment information for the most important EWPs used in Australia in situations requiring treatment.

Table 6. Summary of treatment information for EWPs in Australia (Readers should consult AS1604 for full and exact details)

EWP	Hazard Class	Typical application methods	Approved preservatives*
Plywood	H1 (inside above ground); lyctid borers	All lyctid susceptible veneers treated.	Boron, CCA, ACQ, bifenthrin, permethrin, cypermethrin, deltamethrin, fluorine
	H2 (inside above ground); borers and termites	Pressure treatments of veneers or plywood (envelope). Glueline with/without face treatments	CCA, ACQ, bifenthrin, permethrin, cypermethrin, deltamethrin, copper azole, arsenic, imidacloprid and thiacloprid.
	H3 (outside above ground); moderate decay, borers and termites.	Pressure treatments of veneers or plywood (envelope). Glueline - only treatment not approved.	CCA, ACQ, copper azole, bifenthrin, permethrin, cypermethrin, deltamethrin, tin compounds, Cu napthenate, propiconazole, tebuconazole, creosote, BAC (Benzalkonium chloride)
	H4 (outside in-ground); severe decay, borers and termites.	Pressure treatments of veneers or plywood (including envelope). Glueline-only treatment not approved	CCA, ACQ, Copper Azole, Creosote/PEC (Pigment emulsified creosote).
	H5 (Outside, in-ground contact with or in fresh water); very severe decay, borers and termites.	Pressure treatments of veneers or plywood (including envelope). Glueline-only treatment not approved	As per H4
	H6 (Marine waters); Marine wood borers and decay	Pressure treatments of veneers. Envelope and Glueline-only treatment not approved.	CCA, Creosote/PEC (Pigment emulsified creosote).

EWP	Hazard Class	Typical application methods	Approved preservatives*
LVL	H1	As for plywood	As for plywood
	H2	As for plywood	As for plywood
	H3	As for plywood	As for plywood
	H4	As for plywood	As for plywood
	H5	Pressure treatments of veneers. Glueline-only treatment not approved.	As for plywood
	H6	NOT PERMITTED	NOT PERMITTED
Glulam	H1	Pressure treatment of susceptible sapwood timber before fabrication	As for plywood
	H2	Pressure treatment of timber before fabrication. Envelope treatment after fabrication.	CCA, ACQ, Copper Azole, Permethrin, Deltamethrin, Cypermethrin, Bifenthrin
	H3	Pressure treatment of timber before fabrication.	CCA, ACQ, Copper Azole, Propiconazole, Tebuconazole, Permethrin, Deltamethrin, Cypermethrin, Bifenthrin, tin compounds, copper napthenate, creosote
	H4	Pressure treatment of timber before fabrication.	CCA, ACQ, Copper Azole, Creosote
	H5	NOT PERMITTED	NOT PERMITTED
	H6	NOT PERMITTED	NOT PERMITTED
CLT	No specifications in AS1604	No specifications in AS1604 – currently not treated.	No specifications in AS1604– currently not treated.
Reconstituted wood products including particleboard, OSB and fibreboard	H1	All particles treated before fabrication	As for plywood
	H2	All particles treated before fabrication and/or panel envelope treatments. Also glue treatments and/or face only treatments.	Depending on application method – arsenic, CCA, ACQ, Copper Azole, bifenthrin, permethrin, cypermethrin, deltamethrin, Imidacloprid. Zinc borate.

EWP	Hazard Class	Typical application methods	Approved preservatives*
	H3	All particles treated before fabrication and/or panel envelope treatments.	CCA, ACQ, Permethrin, Cypermethrin, Deltamethrin, BAC, Copper Azole, Creosote, TBTO, TBTN, propiconazole, tebuconazole, bifenthrin, zinc borate
	H4, H5 and H6	NOT PERMITTED	NOT PERMITTED

*Refer to AS1604 – some of these are permitted only with certain types or solvents and/or in combination with other preservatives

There is also some use of imported treated EWPs in Australia -e.g. – imported incised and pentachlorophenol treated Douglas fir glulam from Canada which is used in small bridges. Also, insecticide treated LVL is imported from the NW USA region.

Table 7 shows estimated EWP annual consumption volumes in Australia. In terms of product consumption volumes, by far the most important EWP in Australia is particleboard.

Table 7. Estimated annual consumption of various EWPs in Australia

EWP	Annual Consumption	Data Source
Particleboard	1.087 M m^3 (2016-2017)	ABARES, 2018
MDF	625,000 m^3 (2016-2017)	ABARES, 2018
Plywood	519,000 m^3 (2016-2017)	ABARES, 2018
LVL	218,000 m^3	Estimated based on ABARES and FWPA* data
Hardboard	115,000 m^3	Estimated based on ABARES and FWPA* data
Glulam	45,000 m^3	Estimated
OSB	37,769 m^3	Estimated based on ABARES and FWPA* data
CLT	5000 m^3 (based on imports only – doesn't include XLAM production)	Estimated based on ABARES and FWPA* data
I-Beams	10 M lineal m	Estimated based on ABARES and FWPA* data

*Special acknowledgment to Jim Houghton, FWPA for his assistance.

Estimated proportions of each EWP category in the Australian market that are treated are provided below *(estimates provided by various industry sources who prefer to remain anonymous)*:

Particleboard- approximately 20-30% of particleboard flooring is H2 treated mainly with permethrin. Flooring is about 15% of the total market for particleboard.

Hardboard and MDF – very little if any treated

Plywood- roughly 8-10% of plywood is treated. Mostly H2, but also H3. Treated plywood products include cladding, bridge decks, noise barriers and some flooring. Bifenthrin or imidacloprid glueline, CCA, ACQ and LOSP (with azoles and permethrin) are common treatments.

LVL- Around 25% is treated. Mostly H2, but some H3 with LOSP for exterior deck joists and bearers. Bifenthrin or imidacloprid glueline and CCA, ACQ and LOSP (with azoles and permethrin) are common treatments.

Glulam- Approximately 35% of hardwood glulam and up to 50% of softwood glulam is treated.

OSB- The OSB web proportion of I-Beams if often treated, usually as H2S.

CLT – currently the majority (if not all) of imported CLT is not treated. X-LAM have just commenced production in Australia and have indicated that they will be supplying treated CLT.

I Beams- Around 40% is treated to H2.

Particular issues and opportunities

There is some concern within the Australian timber industry about the adequacy of the official standards and protocols relevant to timber durability and preservative treatment. The key standard, AS1604 is currently undergoing a major review. There has been much debate amongst the committee members and industry more widely regarding items relevant to this standard such as: (*these are the opinions of various stakeholders consulted during the study*)

- Definition of penetration and how it should be assessed, in particular, the suitability of alternative assessment methods to spot testing such as penetration assessment by laboratory retention analysis.
- General structure of the standard and some suggesting that it should be more performance based. There have been arguments put forward suggesting that the standards for wood durability should be modelled on the engineering approach to timber structural performance – timber durability and structural performance are closely related (Personal Communication, Geoff Stringer, 2018).
- Inadequacy of some protocols – particularly for testing the efficacy of wood preservatives; for e.g. inadequate provisions for testing the performance of preservative treated wood or untreated wood in situations which better reflect market reality – in terms of common wood dimensions, grades, mixtures of sapwood and hardwood. Currently preservative efficacy testing is undertaken mainly on small, fully treated sapwood-only sections. Need for an improved suite of performance tests that

can evaluate the performance of treated and untreated woods in situations that better reflect available timber resource characteristics and real market requirements.
- Need for the standard to better accommodate the diverse hazard environments in Australia, different application situations, variable requirements for timber service lives and to reflect a better understanding of community expectations and needs.

Another important issue currently in the Australian treated timber industry is the non-existence of a third-party quality monitoring scheme. Some companies have opted for CodeMark certification, however many believe that treated timber quality control in Australia could improve for the benefit of the long-term future of the industry. It is believed that the new AS1604 standard (currently in draft form) will help to support the advancement of the industry because it now contains verification requirements based on probabilistic criteria (Personal Communication, Andy McNaught, 2018).

Another issue is also the minimal timber durability and treatment (both traditional and novel modification approaches) R&D that is occurring within Australia compared to the scale of work that is underway in other regions such as Europe and North America. There is also generally a recognised need for improved education of consumers, builders, designers and others regarding timber durability and treatment. A partnership between the Forest and Wood Products Australia (FWPA), University of Sunshine Coast (USC), Department of Agriculture and Fisheries Queensland (DAF) and University of Queensland (UQ) recently established the National Centre for Timber Durability and Design Life to address many of these above-mentioned issues.

Experts within the industry suggest that there is still much to learn about EWP utilisation in Australia. Compared to solid wood products there is a shorter history internationally of EWP use.

Some stakeholders in the Australian timber industry are also advocating for the mandatory treatment of EWPs such as CLT and other mass timber elements in structurally critical and difficult to access applications, particularly in high-occupancy, multi-residential and commercial buildings. This is because despite all the best intentions with design, construction, monitoring and maintenance practices, there are often failures and the consequence of failure could be catastrophic in terms of loss of human life, financial costs as well as jeopardising the long-term future of the wood products industry in mid-rise and high-rise construction. For these reasons, many believe that a precautionary ‘preservative treatment’ approach is warranted.

Some more specific technical items mentioned during discussions with stakeholders included:

- Need to review the Australian standards relevant to the acceptable moisture content of wood after treatment. Australia is considered to be much more demanding and restrictive with respect to this issue and the need for re-drying of treated wood, compared to international criteria. This matter has great relevance for wood preservative treatment options and costs.
- Need for research trials on EWP durability, particularly envelope treated EWPs. It was mentioned that there appears to very little data available on the durability performance of LOSP envelope treated EWPs.
- Consideration of the end of life aspects of treated and non-treated EWPs.
- Wood preservative health and safety matters and waste management.

- Concern over the impact of wood preservatives on the long-term effectiveness of adhesives and the long-term integrity of the glueline.
- Concern over 'glue durability' in ground contact applications, with some suggesting that there is limited data on this, even though products such as plywood can be used for these applications (e.g. H4).
- The extensive maintenance requirements for coatings and finishes; and failures of coatings and finishes for EWPs used in exterior applications. This problem has been shown to be exacerbated with some consumer preferences to use dark paints and coatings that absorb more heat and result in checking that can expose untreated wood beneath envelope treatments.
- Concerns over the long-term performance of envelope treatments, especially where timber elements are reworked after treatment, or other building practices or weathering exposes untreated non-durable wood beneath the envelope treatment.
- Poor quality of imported EWPs such as plywood, LVL and glulam that don't conform with Australian standards.
- Delamination, glueline and timber cracking in Glulam products
- Poor treatment quality of EWPs (only seen as a problem by a very small number of stakeholders).
- Poor design, building, detailing, finishing and maintenance practices resulting in premature failures of EWPs – mainly decay caused by water ingress.
- Need for models for moisture ingress and decay development rates– particularly in EWPs and building systems.
- Many corrosion problems with metal connections leading to premature failures of timber structures.
- Need for improved predictive service life models – updating and building on what already exists.
- Given growing global restrictions on many biocides currently used as wood preservatives, there is an urgent need to test and develop alternative wood preservative active ingredients.
- Development of reliable, accelerated durability and wood preservative efficacy test methods – that better reflect market and consumer expectations.
- Ongoing durability testing to reflect changing forest resources.
- Accurate rapid penetration and retention analysis of wood – e.g. handheld tools
- Modified wood treatment options – therefore not using biocides
- Greater emphasis on the weathering problems with EWPs and need for R&D on maintaining aesthetic performance of wood. It has been suggested that too much consideration is sometimes allocated in Australia to decay and insect durability, whereas the adverse effects of weathering such as splitting, checking, greying and fastener corrosion are also critical in terms of maintaining woods attractiveness to consumers and overall market share.
- Development of affordable and effective fire-retardants
- Greater promotion of the benefits of using treated wood in general and more specifically treated EWPs.

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