WORLD CONFERENCE ON TIMBER ENGINEERING 2025
BRISBANE, AUSTRALIA

Advancing Timber for the Future Built Environment

TIMBER CIRCULARITY: SOLUTIONS MATRIX FOR A TIMBER CIRCULAR BIOECONOMY

Penelope Mitchell[1], Martin Strandgard[2], Melanie Harris[3], and Tripti Singh[4]

ABSTRACT: Timber is an ideal resource for the circular bioeconomy with the potential to aid the transition towards a net positive future. Preservative treated timber (PTT) and engineered wood products (EWP) can allow greater high value use of wood resources, can increase timber strength and durability, and store carbon. Adhesives and treatments however are problematic when re-circulating or recycling resources into new applications. With the Australian Government calling for a circular economy (CE) by 2030, all resources will have to be reused and recycled rather than moving linearly from use to landfill. Despite growing awareness of the benefits of a CE there has been little adoption of this approach within the timber supply chain. A clear understanding of available resources is vital for determining potential solutions for end-of-life (EOL) timber.

The Timber Circularity Project is a three-year national project spearheaded by The National Centre for Timber Durability and Design Life (NCTDDL) which aims to understand EOL resources available and potential solutions that will meet regulatory and logistics challenges. The aim of the project is to delineate circular pathways for PTT and EWP and aid the transition of the timber supply chain to a CE. The volume and condition of unused resources, logistics, regulations, and solutions are being geospatially mapped.

This paper presents an overview of a solutions matrix designed to evaluate potential pathways for enabling a timber CE. Rather than following a linear cascade from reuse to energy recovery, timber should be assessed within a broader framework that considers factors such as scalability, ecological impact, and establishment costs. Organizing solutions within a structured hierarchy allows for a more comprehensive evaluation against these key considerations. The matrix has been applied to identify the most viable options for a pilot demonstration of CCA PTT vineyard posts, set to commence in mid-2025. As new solutions emerge, the matrix will continue to evolve, supporting the advancement of a sustainable timber CE.

KEYWORDS: circular economy, bioeconomy, end-of-life solutions, preservative treated timber, engineered wood products.

1 – INTRODUCTION

With Australia depleting resources at an accelerated rate, and simultaneously generating a growing amount of waste and emissions, conversations around the bioeconomy and circular economy (CE) are increasing. The CE is a radical move away from a linear economy moving raw materials through the supply chain from production and use through to landfill [1]. A CE enables resources to re-enter the supply chain, circulating products and materials through multiple lives at their highest value then cascading through reuse, recycling and recovery [2]. The Circular Economy Diagram (Figure 1) shows stages along the supply chain where opportunities to apply circular economy principles are possible. The bioeconomy is based on renewable, biological resources; substituting carbon-intensive products, such as steel, concrete and plastics, with fossil fuel free alternatives, including forest and wood products [3].

[1] Penelope Mitchell, National Centre for Timber Durability and Deign Life (NCTDDL), University of the Sunshine Coast (UniSC), Queensland, Australia, pmitche2@usc.edu.au

[2] Martin Strandgard, NCTDDL, UniSC, Queensland, Australia, mstrandg@usc.edu.au

[3] Melanie Harris, NCTDDL, UniSC, Queensland, Australia, mharris3@usc.edu.au

[4] Tripti Singh, NCTDDL, UniSC, Queensland, Australia, tsingh1@usc.edu.au

https://doi.org/10.52202/080513-0581

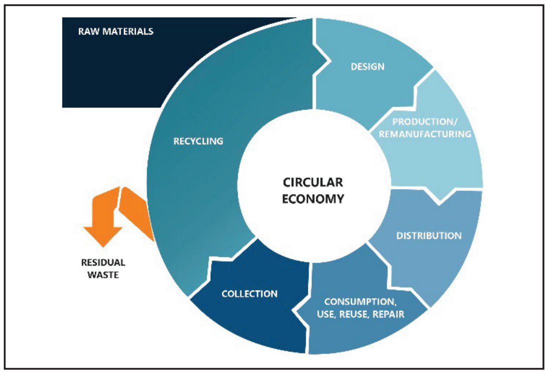

Figure 1 CE Diagram (based on National Waste Policy CE Diagram)

A circular bioeconomy can provide a pathway for reducing fossil fuel use and replacing it with renewable natural resources, addressing supply chain issues, and mitigating climate change in a move towards a sustainable future [4]. To achieve climate neutrality by 2050, a CE needs to be widely adopted and a transition towards a regenerative, bioeconomic model, enacted.

The move towards a low-carbon, circular model represents an opportunity to address resource risks, waste, and emissions while increasing economic security. The Australian Government is calling for a CE by 2030 to help tackle the global challenges of climate change, biodiversity loss, waste, and pollution while meeting net zero commitments [5]. In the transition to a circular bioeconomy, the Australian forest and wood products (FWP) industry has a critical role. Timber is the ultimate biological and renewable resource contributing to climate change mitigation through carbon sequestration. Trees remove CO2 from the atmosphere and retain it while timber remains in use. When wood replaces non-wood materials, greenhouse gas emissions are reduced. Using timber over multiple life cycles ensures long-term carbon storage and increased resource efficiency [6]. Additionally, PTT and EWP provide significant advantages; the life of PTT is extended over ten times that of untreated timber [7] and EWP manufacture increases use of wood resources, structural integrity, and potential size of a structural member. Chemical treatments and adhesives however become problematic when timber products reach end-of-life (EOL) and need to be recycled. It is estimated that 60% of timber resources in Australia are diverted to landfill however this information is limited as the National Waste Report focusses on waste managed by the waste and resource recovery sector rather than the resource as a whole [8]. It is timely however that an industry which contributes to a bioeconomy, addresses the challenges associated with PTT and EWP in a CE.

2 – BACKGROUND

The Timber Circularity Project (TCP) is a three-year industry-funded national project that aims to identify and implement strategies and solutions to keep wood fibre in the supply chain within a CE. Led by the National Centre for Timber Durability and Design Life (NCTDDL) the project is funded by Forest and Wood Products Australia (FWPA) along with a consortium of timber producers, chemical suppliers, and timber users. The project focusses on PTT and EWP which are currently problematic at EOL due to chemical treatments and adhesives, particularly PTT vineyard posts and utility poles, frame and truss (F&T) timber, and EWP such as particleboard, plywood and medium density fibreboard (MDF). The reuse and recycling opportunities for these products are not currently well understood particularly in the context of a circular economy, and all EOL PTT and EWP are currently categorised as controlled or priority waste by Australian state Environment Protection Authorities (EPA). This is despite products containing varying treatment and glue types and amounts. The project's goal is to identify circular pathways for PTT and EWP in Australia.

3 – KEY PROJECT TASKS

A range of research has been undertaken for the TCP to identify opportunities to undertake a pilot demonstration, as a major project outcome. The selected pilot offers a solution for EOL CCA PTT vineyard posts, which are an important resource in the Australian viticulture industry with an estimated 71 million posts currently in use [9]. Conducting a pilot using these posts may provide a solution for an EOL timber product with limited reuse/ recycling options. The key project tasks, targeted at all PTT and EWP resources, include:

3.1 QUANTIFYING RESOURCES

This task includes quantifying current and projected volumes of EOL PTT and EWP resources available and their distribution using surveys, site-visits, and discussion. These information sources have provided a snapshot of resources and their geographic distribution so that appropriate EOL solutions can be determined. Understanding where resources are located, what currently happens with these resources, costs associated with current EOL options, including landfill costs for PTT disposal on a state basis, is important in determining costs for future circular options. Reports have been produced outlining EOL vineyard post and F&T resources in Australia, with findings including:

https://doi.org/10.52202/080513-0581

- Vineyard posts become part of the waste stream due to vineyard removal/ post breakage with ~1.7million posts removed from vineyards each year [9].
- There are 273 unique F&T facilities processing around 2.5 million cubic metres framing timber annually. Unused resources generated by F&T facilities vary over the course of the year, but on average, small facilities (21% of all facilities) produce around 6m^3 of clean offcuts and sawdust per month (medium (40%) 16m^3; large (18%) 32m^3; extra-large (21%) 81m^3) [10].

Reports detailing utility poles and EWP resources are currently being completed using data obtained from surveys, site visits and discussions. Some of the initial findings include:

- 58,000+ utility poles are replaced annually in Australia, just over 1% of the total posts in use.
- Manufacturers of EWP generally have little unused resources, utilising them for energy.
- Manufacturing companies using EWP (particleboard, MDF, plywood) including shopfitters, furniture & cabinet makers, dispose of valuable resources at significant cost, give away small amounts or reuse onsite (packaging). A very small amount is collected or delivered to recyclers at cost to the company.

3.2 RESOURCE CONDITION

Resources have also been analysed for their condition at EOL to understand the ability for reuse/ recycling. This includes understanding retained treatment levels in PTT for ongoing durability, strength for reuse applications, and levels of contaminants such as nails. The information, undertaken by visual inspection during site visits, obtaining samples, lab analysis and strength testing, will be useful to determine future opportunities. Analysis of treatment levels in stockpiled posts (removed due to mechanical damage during harvesting after 17-26 years in service) showed that retention of CCA generally met the minimum level specified in the Australian Standard (AS/NZS 1604) for inground use. This indicates that reuse options where durability is required, such as fencing, are possible [11]. In addition, strength testing showed that EOL vineyard posts retained sufficient strength and consistency for repurposing as agricultural posts or other low-stress outdoor applications [12]. Visual inspection and understanding of sorting methods at F&T and EWP facilities, showed that the timber offcuts and sawdust collected are generally uncontaminated and separated from other waste sources (nails, plastics, food waste, etc.) generated on-site.

3.3 LOGISTICS

The Australian context is unique compared to other countries in terms of the vast distances between cities. Analysis of collection, transport and infrastructure is important to understand a CE reality. There are costs and emissions associated with processing, loading/ unloading, and transporting resource. Information regarding distances and available truck types and their characteristics will provide a better understanding that can help inform best options for a CE. A case study undertaken for the TCP showed chipping biomass prior to transport would reduce costs and emissions, however chipping at each facility was likely to be more costly overall [13]. Reductions in transport cost through use of larger trucks is unlikely to outweigh the additional costs of moving a chipper between facilities. More case studies like this one, identifying logistic outcomes, particularly the benefits of backloading, are currently being documented. This information will provide valuable information on reducing costs associated with logistics, which will lead to overall emissions reductions and positive CE outcomes. It will also help pinpoint locations for regional recycling and processing hubs and facilities, which will aid government with infrastructure development.

3.4 REGULATIONS

National, state and territory regulations and policies have been reviewed for the TCP to understand barriers and enablers of a timber CE [14]. EOL PTT and EWP are classified by state EPAs as controlled or priority waste, irrespective of the type of treatment or adhesives being used. This classification means that in most cases EOL PTT and EWP require disposal at appropriately licensed facilities with advanced leachate management systems which incur significantly higher disposal costs than general waste. The state of Queensland is a major exception, with alternative pathways approved by the state EPA for reuse or recycling EOL PTT.

Analysis of landfill audits and discussions with waste contractors as part of the TCP, show that EOL timber is mostly being landfilled, burnt, or stockpiled, awaiting a solution. The risks associated with EOL PTT and EWP need to be addressed by regulations to avoid health or environmental impacts and need to be understood in context of a CE. The varied approaches to management of EOL PTT and EWP in Australian states is a major barrier to the adoption of alternatives to landfill. The impact regulations in most states are having on the circularity of timber cannot be underestimated despite

https://doi.org/10.52202/080513-0581

some of the policies and practices being left deliberately vague so that risks and opportunities can be addressed on a case-by-case basis. Most states' regulatory provisions fail to reflect potential reuse and recovery of PTT in a CE which would potentially help to address climate change factors whilst enhancing Australia's economic development.

3.5 GEOSPATIAL MAPPING

A geospatial map has been developed to provide a visual understanding of EOL PTT and EWP resources, solutions, and infrastructure. The newly developed Timber Circularity Resource Map (available at timbercircularity.com.au) has been designed as a complete reference for an Australian timber circular economy (Figure 2). The map displays timber resources available, potential solutions, and available infrastructure including councils progressing towards a CE, as well as landfills/ transfer stations licenced to accept PTT. These facilities can potentially support recycling infrastructure in the future. Accompanying information provides details on estimated volumes of timber resources available, facility size, resource type and condition, treatment type and percentage treated, and assumptions made. Regulatory information around potential use of EOL PTT in new products is included for all solution providers and is provided on a state-by-state basis. Councils with CE or zero waste initiatives have been mapped and the initiative is identified with details about plans or strategies. For licenced landfill and transfer stations, details are provided about current costs of disposal, including waste levies, and notes on acceptance of PTT. There are additional built-in features within the map to help with a timber CE, including tools to search for resources or solutions within a particular radius, and downloadable data of facilities in a specified location. This feature helps drill down into amounts of resource, location, and distances. It is hoped that the timber circularity geospatial map will become the CE reference point for the whole of the timber industry in the future, as well as help identify the best locations for the pending pilot demonstration.

3.6 PILOT

The pilot is a key task for this project focussing on EOL CCA PTT vineyard posts, due to the risks associated with current stockpiles, particularly fire. The timber posts are renewable, durable, easy to handle and install, cost effective and produced from sustainably managed plantation thinnings, storing carbon beyond their service life. Predominantly treated with copper chromated arsenate (CCA) (~ 80%) the treatment extends the life of the posts to 30+ years by providing protection against decay and insects such as termites but becomes hazardous waste at EOL [15]. Alternative materials, including steel and concrete, are more energy intensive generating greater emissions during manufacture, and fall outside a bioeconomy as they are non-renewable [16]. Thus, it is vital that solutions are determined for the EOL PTT posts.

The tasks detailed above have helped identify considerations for the pilot including the amount of resource available in any given region, condition of resources, logistic impacts on the site of the pilot, and potential locations based on state EPA regulations. An analysis of national and international solutions has been undertaken as part of the TCP to better understand potential parties involved (demonstration partner, transport company, contractors), amount of resource required for trial, costs involved, time required, markets for new products, advantages, challenges, and the way forward.

The remainder of this paper focuses on CE opportunities, and the hierarchy matrix which has been created to assess pilot options against a range of considerations. The solutions that are being further investigated for pilot demonstrations are also discussed.

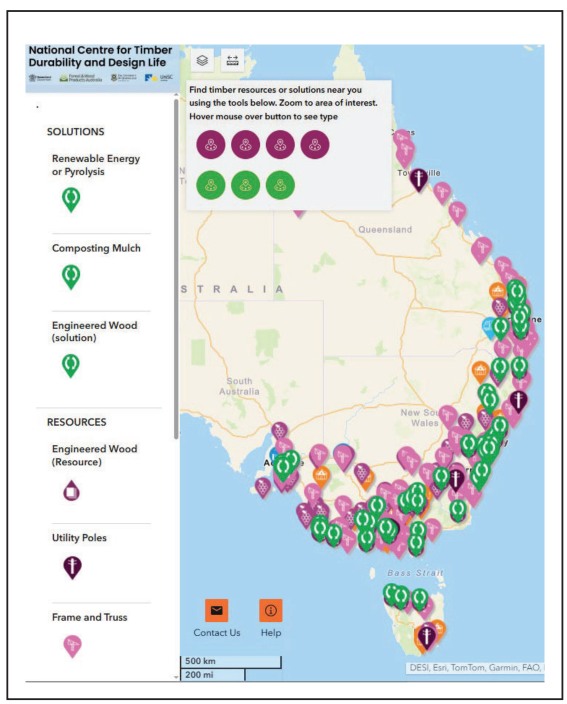

Figure 2 Timber Circularity Project Geospatial Mapping

4 – SOLUTIONS FOR TIMBER IN A CIRCULAR ECONOMY

Within a circular bioeconomy there are stages along the whole supply chain where opportunities to apply CE principles to renewable materials are possible. There is a whole raft of strategies within the harvesting, design and innovation, manufacture, transportation, and procurement stages to positively influence a CE, including designing out waste, design for disassembly or recoverability, resource efficiency or service solutions including leasing models, buy local, and establishing regional hubs (Figure 5). There are also strategies to ensure a product remains in use or cycles through multiple reuse cycles without the need for further processing. For example, in the case of vineyard posts, replacing current mechanical harvesting equipment, which causes post breakages, with robotic harvesting, may be worth investigating but is outside the current project scope. In this instance we are interested in the material flows and opportunities to cycle existing EOL materials back into a circular system.

Local and global solutions for EOL PTT and EWP have been investigated and mapped by hierarchy of reuse and recycling options against a range of considerations including economic, ecological, and technical considerations. This matrix has provided useful information for better understating and decision making around not only the pilot opportunities but for a timber CE in general. The matrix is contained within a large spreadsheet therefore a discussion of the hierarchy and the considerations each solution has been mapped against, are presented (Figure 3).

POTENTIAL SOLUTIONS	CURRENTLY AVAILABLE	ORGANISATION	LOCATION	DETAILS
REUSE, REPAIR & REPROCESSING				
CCA Treated Post Reuse as Fencing	√ (NZ only)	RePost	NZ	Reuse of vineyard posts - processing at site
CCA Post repair	√	OcLoc	Edwardstown, SA	Repair post rammed into ground alongside broken post & attached using
ENGINEERED WOOD PRODUCTS (RECYCLING)				
Glulam	√	Megabeam	Caloundra, QLD	Treated frame & truss offcuts greater than 300mm are finger jointed
Particleboard	√	Laminex	Gympie, QLD Hazelmere, WA	Will accept clean timber chips for particleboard - EWP or PTT
PYROLYSIS & BIOCHAR				
Pyrolysis	√	Pyrocal	Toowoomba, QLD	Systems available
MULCH & COMPOST				
Mulch for composting (trials)	√	Mulbartons Transport	Mulbarton, SA	Trialling composting of CCA treated timber
ENERGY				
Bioenergy	√	MSM Milling	Manildra, NSW	One of first examples in Australia. Replaced LPG fuelled boilers with a 5

Figure 3 Partial snapshot of Timber Circularity Matrix.

4.1 Hierarchy

Hierarchies often suggest a linear cascade from a higher-value products through decreasing values, rather than a circular system in which multiple pathways interconnect and result in new products and innovations. The circular system (Figure 5) details many of the possible opportunities for timber to re-enter a circular system along the supply-chain. Recycling can potentially produce higher-value or higher-performance than the initial product. In the case of wood products, offcuts from frame and truss facilities, for example, can be utilised in glue laminated timber (glulam) which is a structurally reliable, stable, strong, and durable product that can be used in high value applications. In a CE, materials should not cascade linearly through reuse, recycling, to energy, with each step a decreasing value, however it is important to understand different value applications that can potentially extend the life of a material. To that end, a simplified hierarchy has been used for the TCP to categorise solutions (Figure 4).

Reuse, Repair, Reprocess

Retaining material at the same hierarchical level is beneficial for a CE. Broken posts for example can remain in-situ for greater lengths of time if repaired using star pickets, timber supporting posts or proprietary products. The focus for the pilot however is the current post stockpiles which could consist of over 20 million posts [9]. Reusing posts in agricultural applications has been considered as a pilot opportunity. As described earlier, the posts have been assessed for minimum CCA retention standards but require processing, including removal of fasteners and fitting and cutting to standard size of over 1.6m in length.

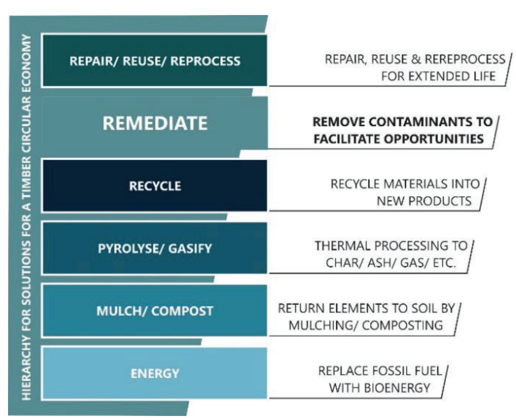

Figure 4 Timber Circularity Hierarchy of Use

https://doi.org/10.52202/080513-0581

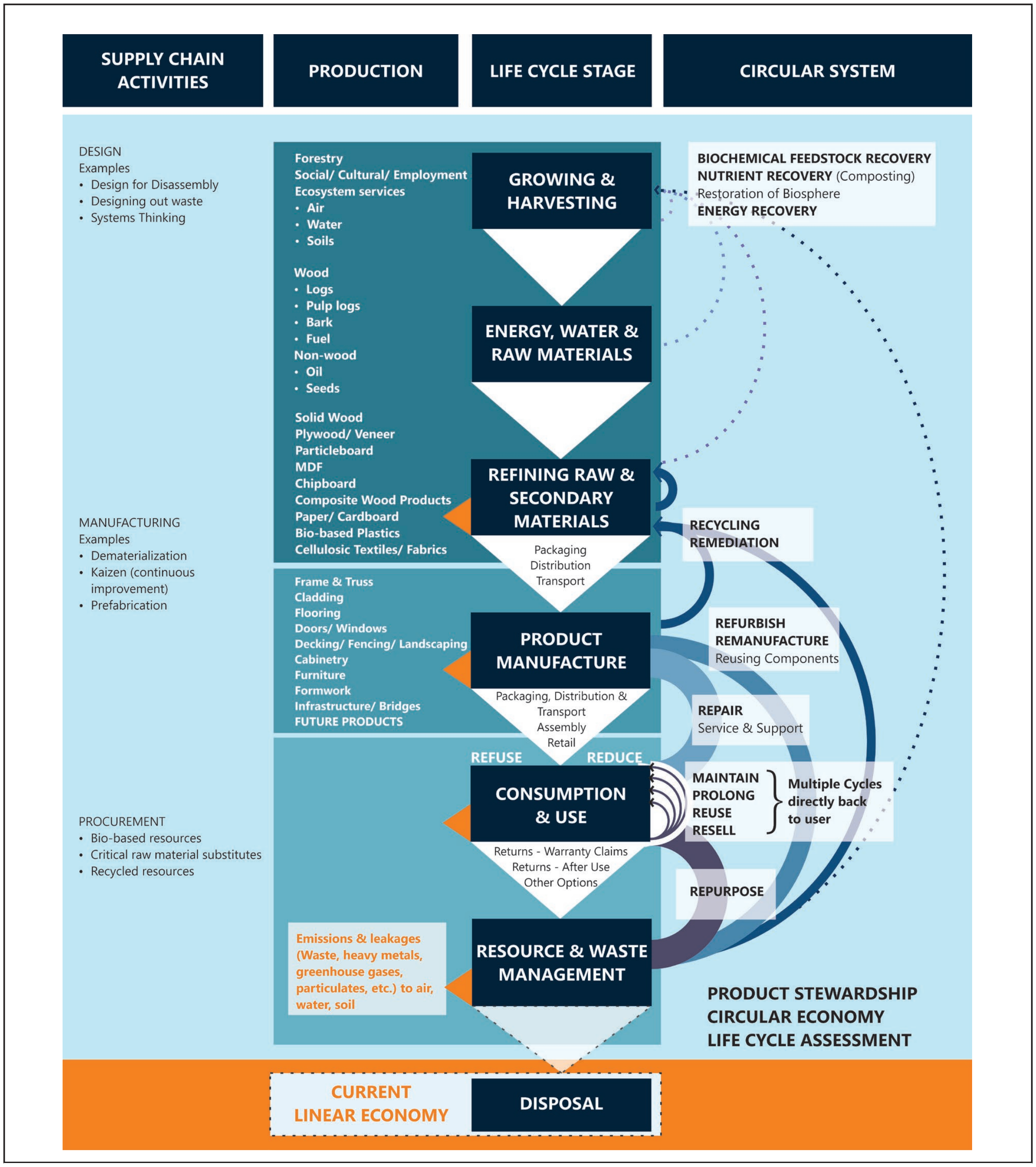

Figure 3 Supply Chain Circular System for forest and wood products

Remediate

Remediation may be significant for PTT for recycling, composting or energy recovery applications. AS 5605-2007 Guide to the safe use of PTT uses a precautionary approach for heavy metal allowances for these purposes[17]. Remediation of PTT has been investigated for over two decades but has not been scaled for any serious endeavours due to the expense and the lack of market for the low-value fibre. A CE may make remediation more viable.

Recycle

Recycling EOL timber could produce higher value, high-performance, structural timber products, circulating materials at similar or higher value [18]. EOL timber can be recycled into products including EWP (particleboard or glulam) or composite wood products (wood-cement or wood-plastic composites). Meeting the demand for these products and new innovative wood fibre-products which support a bioeconomy will require a substantial input of post-consumer timber resource. Recycling EOL PTT vineyard posts for example into a high value essential building product is a valuable circular economy outcome. Particleboard, for example, is a common use for EOL wood resources in Europe, with approximately 46% of wood waste being used for this purpose [19]. While there are no Australian standards for heavy metal levels in particleboard, if small amounts of EOL CCA PTT ($1000m^3$) were included in $500{,}000m^3$ particleboard (as produced at Borg's Oberon facility), the CCA levels would be well under EU Ecolabel levels and below the lowest treatment hazard class (H1) typically used for furniture and joinery. Particleboard with up to 50% CCA PTT has been found to be of equal quality to that made solely from untreated timber [20] and reduces water absorption and thickness swelling, and increases modulus of elasticity (MOE) [21]. There are many opportunities for recycling EOL wood resources, but regulatory challenges must be addressed.

Pyrolyse, Gasify

Pyrolysis and gasification use a thermochemical decomposition process to produce fuels, biochar and gas products [22]. PTT and EWP require further investigation for pyrolysis in the Australian context, but research has shown that during pyrolysis of CCA PTT, the copper and chromium components are largely retained in the biochar irrespective of temperature, while the proportion of arsenic volatilised increases with increasing temperature [23]. It has been determined that at a pyrolysis temperature of 350°C, copper, chromium and arsenic particles are largely retained in the ash [24] and could potentially be separated and recovered. The reuse of these metals requires more understanding in terms of form, economics of separation and recovery. The resulting biochar however should have a market in industrial uses, for example as a replacement for coal and coke in steel manufacture [25] or potentially as a high-value hard carbon for the use in novel bio-based batteries for electric cars [26].

Compost, Mulch

The benefit of timber, is that it fits within the bioeconomy, so can ultimately be composted or returned to soil. Any form of PTT however is prohibited by most state EPA regulations from being used in compost or mulch [14]. The Australian standard for mulch, soil conditioner and compost (AS4454-2012) specifies maximum concentration allowances for copper, chromium and arsenic and researchers are currently examining the potential of C&D waste as compost for specific agricultural applications and biological remediation of CCA PTT by composting. Remediation may be a required step in cycling PTT and EWP back to soil [27] if compost and mulch retain unacceptable levels of heavy metals. Regulatory change may allow higher heavy metal concentrations in compost and mulch for applications where no food crops are grown, and human contact is unlikely (e.g. roadsides and forested land).

Energy

Although energy is considered at a lower level in the hierarchy, using EOL timber for energy can reduce overall emissions, due to reduction in the use of fossil fuel alternatives. Although there has been some discussion in Australia that wood may be more beneficial in landfill storing CO2 [28], wood takes significant space in landfill where it will ultimately break down and release methane, annulling the significant benefits of carbon sequestration. In Europe where landfill space is at a premium, PTT and EWP join other waste being burnt for renewable energy [29]. While waste to energy reduces the amount of waste to landfill, it limits other possible use of the material as a resource and needs to be fully considered in future CE scenarios.

4.2 Considerations

The matrix of solutions maps the CE hierarchy against a range of considerations to provide a more thorough understanding of how solutions can be implemented for different timber types, and in different regions. The considerations are listed here with examples provided:

Potential Solutions – Listed and categorised under the above hierarchy.

- Reusing CCA PTT posts as agricultural fence posts.
- Recycling CCA PTT into particleboard in small amounts.

Current availability – Indicating national and international availability or stage in development.

- Remediation of CCA PTT by Treated Timber Remediation (TTR) fully developed but looking for funding for infrastructure and regulatory support.
- Pyrolysis systems (Pyrocal) available in Australia but not trialled with different timber types.

Organisation – Organisation with developed solution or solution in operation.

- Recycling EOL pre-consumer resource into particleboard currently undertaken by Borg.
- Energy from C&D waste collected by Resource Co.

Location – detailed suburb and state, or where solution is available for purchase, as a national solution.

https://doi.org/10.52202/080513-0581

Details – providing other relevant details.

- Recycling wood fibre into road infrastructure actively being investigated by Infrastructure Australia.
- Mulch for soil conditioning using PTT and EWP currently being tested by QDAF.

Type of timber – specifying types of timber currently accepted as well as future possibilities.

- Recycling into wood fibre/ cement composites showing promise with CCA treated timber.
- Energy produced from C&D waste at Adelaide Brighton Cement (Adbri) can contain mixed wood waste including a maximum of 2% CCA PTT.

Market – end use of new product market.

- The growing demand for particleboard in Australia will require increasing amounts of timber resource which can be filled using EOL timber resources.
- Bioenergy demand to replace fossil fuel alternatives (MSM Milling).

Economics – including infrastructure costs, ongoing feasibility, labour, transport costs, final product cost, etc.

- Recycling F&T offcuts into glulam is currently only viable with backloading.
- Companies paying for resource to be removed for recycling with recyclers not paying for fibre.

Ecological Considerations – including life cycle impacts, emissions, potential for leaching, etc.

- Thermochemical processing and energy production may need scrubbers to capture emissions.
- Heavy metals may be bound in biochar structure with limited availability in the environment.

Technical Issues - including details of establishment times, resource volumes able to be processed, sorting or preprocessing required, staff requirements, product technical capabilities, etc.

- Biggest challenge for many solutions is separation of different timber types.
- Recycled wood fibre in road infrastructure can possibly strengthen end-product.

Scale – variety of scales required for regional solutions through to large scale infrastructure.

- Mobile solutions for pyrolysis currently being developed by Pyrocal for regional use.
- Particleboard manufacturing generally on a large, centralised scale (Borg, Laminex).

Regulations – where solutions are state based, associated regulatory information is provided.

Pilot opportunities – options that can be explored for trial in 2025 have been noted and include:

- options that are available but have not been trialled with CCA treated timber (pyrolysis)
- pilots that need regulatory exemptions for CCA PTT (particleboard)
- opportunities not undertaken commercially in Australia (CCA post reuse as agricultural fencing).

5 – OUTCOMES AND FUTURE WORK

The matrix of solutions will continue to develop as CE is implemented. It will allow for further understanding of possibilities as many unique solutions are required. Understanding the challenges and advantages of specific solutions will support the transition to a timber circular bioeconomy which will contribute to a sustainable, regenerative timber industry. The matrix will also inform and move forward the pilot demonstration for this project but also other pilots helping to gain a better understanding of regulations, associated risks and suitability for a specific application.

Pilot opportunities can provide information for decision making including evidence on emissions, impacts and logistics, which will in turn aid in the development of a timber CE. Enabling the growing EOL PTT and EWP resource to recirculate in the supply chain will reduce landfill and associated costs and emissions and reduce supply chain reliance on new wood fibre. This will drive economic advancements in the timber industry by reducing costs associated with waste, placing a focus on cost-effective transport and processing methods, creating new opportunities for businesses and reducing requirements for alternatives that potentially have greater life cycle and reprocessing impact. The matrix will also help further develop the regulatory space and provide more consistency and harmonisation to definitions and regulations and policies in Australia. Understanding and addressing regulatory hurdles will ensure that reuse and recycling processes meet all legal requirements. It is envisaged that the matrix will be made available online as part of the TCP website to help build a vision for timber circularity in Australia.

5 – REFERENCES

[1] Circle Economy Foundation. The Circularity Gap Report, Amsterdam: Circle Economy, 2022

[2] European Union. Circular Economy Action Plan: For a cleaner and more competitive Europe, EC, 2020

[3] Hassegawa, M. Van Brusselen, J. Cramm, M. and Verkerk, P.J. Wood-Based Products in the Circular

Bioeconomy: Status and Opportunities towards Environmental Sustainability. Land 2022, 11, 2131.

[4] Muscat A, de Olde EM, Ripoll-Bosch R, Van Zanten HH, Metze TA, Termeer CJ, van Ittersum MK, de Boer IJ. Principles, drivers and opportunities of a circular bioeconomy. Nature Food. 2021 Aug;2(8):561-6.

[5] DCCEEW 2024, Australia's Circular Economy Framework, Department of Climate Change, Energy, the Environment and Water, Canberra, December 2024.

[6] Niu, Y., Rasi, K., Hughes, M., Halme, M., & Fink, G. Prolonging life cycles of construction materials and combating climate change by cascading: The case of reusing timber in Finland, Resources, Conservation and Recycling, Vol. 170, July 2021.

[7] American Wood Preservers' Association (AWPA) Annual Book of Standards. AWPA, Birmingham, Alabama, 2023.

[8] Blue Environment. National Waste Report 2022. Dept. Climate Change, Energy, Environment and Water.

[9] Mitchell, P., Strandgard, M., Singh, T., Ghaffariyan, M.R., & Brown, M. End-of-life timber vineyard posts resource report, NCTDDL, 2024

[10] Strandgard, M. Mitchell, P., & Singh, T. Frame and Truss Unused Resources Survey, Report V4.0 October 2024, Timber Circularity Project, NCTDDL, 2024

[11] Singh, T., Yi, T., Mitchell, P. and Norton, J. Levels of chromated copper arsenate in aged radiata pine vineyard posts. IRG/WP 24-50389, 2023

[12] Yan, Z. & Yerman, L. Performance Assessment of New and Aged Vineyard CCA-Treated Timber Posts, UQ & NCTDDL, Nov. 2024

[13] Strandgard, M. Mitchell, P., & Singh, T. Frame and Truss Offcut Utilisation Case Study, Report V4.0 October, Timber Circularity Project, NCTDDL, 2024

[14] Martin, R. Policies and Regulations Affecting or Restricting the Circularity of Treated Timber and Engineered Wood Products, NCTDDL, 2024

[15] Hann, J., Daian, G., Cooksom, L.J. Przewloka, S. Determination of Acceptable Levels of Preservative Treated Timber in Reuse Applications. FWPA 2010

[16] Trabucco, D. & Perrucci, G. Steel–Timber Hybrid Buildings: A Comparative Life Cycle Assessment Study of Global Warning Potential Impacts.Sustainability (2071-1050). Vol. 17 Issue 2, Jan 2025

[17] Standards Australia. Standard AS 5605-2007 Guide to the safe use of preservative treated timber. Standards Australia, Melbourne, Australia.

[18] Dong, X., Gan, W., Shang, Y. et al. Low-value wood for sustainable high-performance structural materials. Nat Sustain 5, 628–635, 2022

[19] Pazzaglia, A.& Castellani, B. Wood waste valorization in Europe: Policy framework, challenges, and decisional tools. Procedia Environmental Science, Engineering and Management, 10, 345-352. 2023.

[20] Munson, J. & Donatien-Pascal, K. Reconstituted particleboards from CCA-treated red pine utility poles. Forest Products Journal, 48, 55-62., 1998

[21] Clausen, C.,Kartal, N. & Muehl, J. Properties of particleboard made from recycled CCA-treated wood. IRG/WP 00-50146, 2000.

[22] Kan, T., Strezov, V. & Evans, T. Lignocellulosic biomass pyrolysis: A review of product properties and effects of pyrolysis parameters. Renewable and Sustainable Energy Reviews, 57, 1126-1140. 2016

[23] Lundholm, K., Rogers, J., Haynes, B. Bostrom, D. & Nordin, A. Fate of Cu, Cr, and As during the Combustion Stages of CCA-Treated Wood Fuel Particles. Energy & Fuels, 22, 1589-1597, 2008

[24] Helsen, L., Van den Bulck, E. & Hery, J. Total recycling of CCA treated wood waste by low-temperature pyrolysis. Waste Management, 18, 571-578, 1998

[25] Safarian, S. To what extent could biochar replace coal and coke in steel industries? Fuel, 339, 127401. 2023

[26] Jin, Y., Shi, Z., Yang, H. et al From Waste Biomass to Hard Carbon Anodes: Predicting the Relationship between Biomass Processing Parameters and Performance of Hard Carbons in Sodium-Ion Batteries. Processes 2023, 11(3), 764, 2023

[27] Wilkinson, K., Price, J., Biala, J. & McDonald, D. Review of Regulations and Standards for Recycled Organics in Australia. Final Report for Department of Agriculture, Water and Environment, DAWE, 2021

[28] John, S. & Buchanan, A. Review of End-of-life Options for Structural Timber Buildings in New Zealand and Australia. Report no: STIC-2013-01 Version 1.0, University of Canterbury, 2013

[29] Junginger, M., Jarvinen, M., Olsson, O., Hennig, C. & Dadhich, P. Transboundary flows of woody biomass waste streams in Europe, IEA Bioenergy. IEA Bioenergy, 2019

 https://doi.org/10.52202/080513-0581