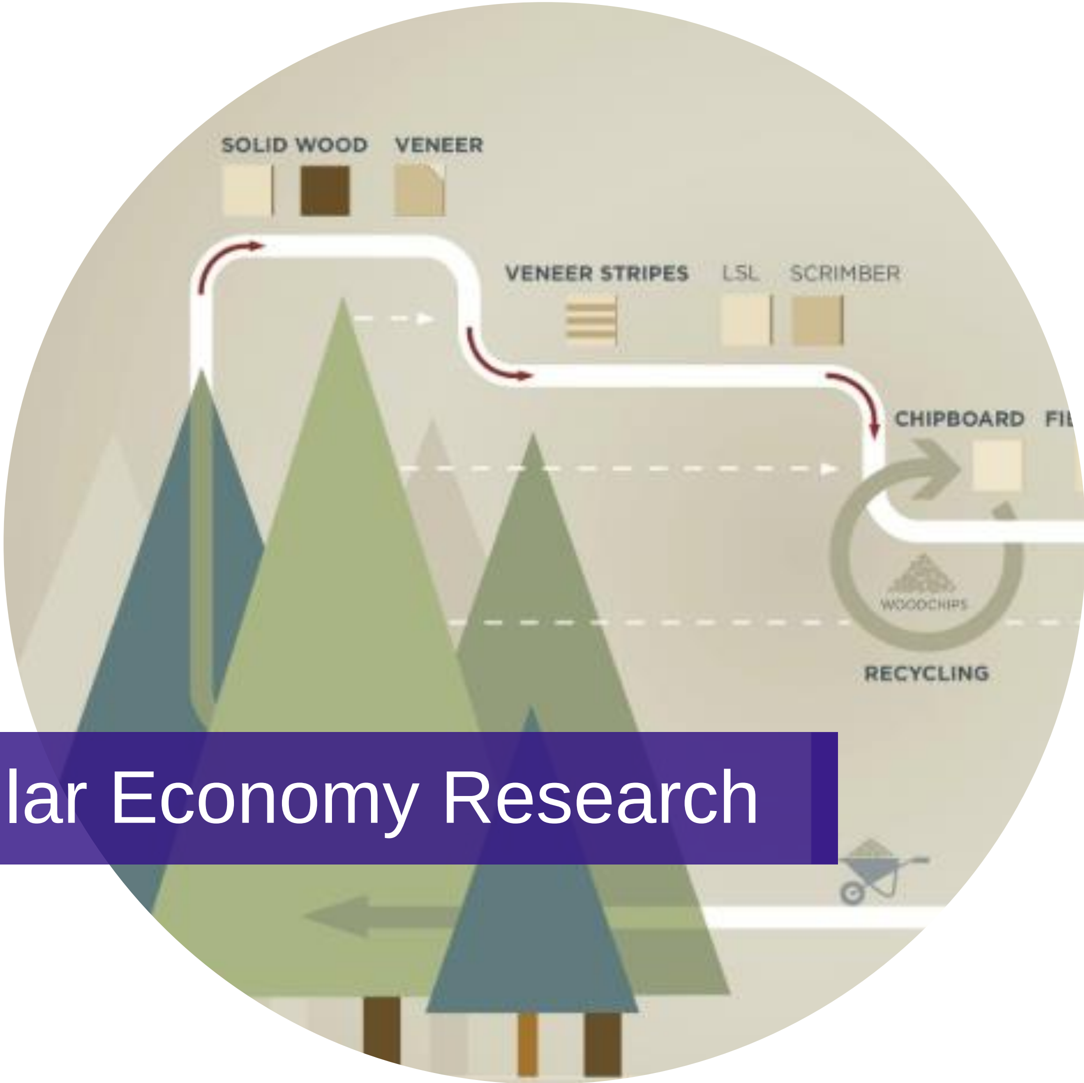

Circular Economy Research

Client:	**Illawarra Shoalhaven Joint Organisation (ISJO)**
Title:	**Circular economy research**
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Executive Summary

The Illawarra Shoalhaven Joint Organisation (ISJO) is interested in opportunities for the region to progress a circular economy so that businesses can minimise the amount of medium-density fibreboard (MDF), particleboard (PB), mixed sawdust, and related material they send to landfill.

We estimate that around 5,031 tonnes of these materials (the Focus Materials) are generated each year from 100 joinery business in the region. Also, 2,566 tonnes of end-of-life material is estimated to be generated each year.

A more circular economy can bring multiple advantages to ISJO

A circular economy is based on the principles of designing out waste and pollution, keeping products and materials in use at their highest value, and regenerating natural systems. The model also includes a shift towards electrification and renewable energy sources and away from linear, fossil fuel-based alternatives.

A more circular economy can help businesses and the ISJO region by:

- delivering access to new markets and customer segments
- providing a competitive advantage
- mitigating regulatory and societal risks
- generating more jobs
- offering more environmentally sustainable solutions (if correctly implemented).

We have taken a circular economy approach to our research and assessed multiple reuse, recycling, and energy recovery solutions that could apply to the ISJO region. Chemical characterisation of the Focus Materials generated by joinery businesses formed part of this research. Results from samples taken from five businesses do not indicate any particular concerns.

Except for reuse options, the NSW Government’s resource recovery regulatory framework is directly relevant to the solutions we assessed. We examine the regulatory framework in detail because it presents substantial barriers to delivering circular solutions locally and across NSW.

Our recommendations focus on facilities with existing resource recovery orders to deliver practical solutions in the 1 to 3-year timeline.

Recommendation 1: Facilitate greater reuse of offcuts

We identified opportunities for joineries and kitchen manufacturers to trade or swap offcuts. ISJO could facilitate a local business-to-business reuse programme in Unanderra and nearby Shellharbour where there is a concentration of similar joinery and kitchen manufacturing businesses.

Alternatively, local reuse centres such as Dunmore Resources & Recycling Centre and Shoalhaven Recycling & Waste Depot at West Nowra could supply suitable size MDF and particleboard offcuts for low-cost sale.

Recommendation 2: Investigate the safe use and potential benefits of Focus Materials in land-applied products.

We recommend the ISJO evaluate the Focus Materials made with the most common resins for their biodegradability and safety in recycled products applied to land (including compost). The research would aim to determine a set rate of engineered wood products allowed in compost for land application, to be approved under a NSW Environment Protection Authority (NSW EPA) resource recovery order and resource recovery exemption.

We recommend that ISJO facilitate research in the safe levels of melamine urea formaldehyde and melamine formaldehyde in land-applied applications.

Recommendation 3: Facilitate Recycling of particleboard offcuts into new particleboard

Recycling is currently the greatest opportunity for particleboard offcuts. reDirect Recycling promotes a low-cost collection service and has facilities at Ingleburn and St Marys for aggregation. They transport particleboard over the mountains to the Borg Manufacturing facility at Oberon.

Given the distances, we recommend an aggregation point in the ISJO region. ISJO could facilitate an aggregation point at polytec's distribution centre in South Nowra whereby polytec vehicles that are delivering a product to joineries backload offcuts to the distribution centre.

thinkstep-anz could assist with a carbon footprint cost/benefit analysis to minimise any negative impacts, as reverse logistics is a recognised impact point for Circular Economy (CE) systems.

Recommendation 4: Facilitate uptake of heat energy generation onsite

Two joineries in the Canberra/Queanbeyan region already employ this option, and joineries are actively pursuing it in the ISJO region. Businesses located in the ISJO region do not have heating needs as great as businesses in the Canberra/Queanbeyan region. However, using sawdust to generate heat energy onsite would result in significant savings from avoided waste disposal costs.

The equipment supplier estimates that a business spending over $8,000 per month on waste disposal costs would find this feasible. We estimate that of the six major joineries in the ISJO region, at least four of those would find a wood waste heater feasible.

To achieve circularity benefits from energy recovery, the heat generated must be used efficiently to displace fossil fuel alternatives. To avoid use as incineration and to be economically viable, the need for year-round energy is preferable.

We recommend facilitating monitoring of the air emissions for current system installations. If they do meet NSW standards, then it is likely that the larger joineries in the ISJO region will take the opportunity to install these appliances.

Recommendation 5: Facilitate recovery of heat energy offsite

For some materials, especially Focus Materials such as end-of-life kitchen cabinets and joinery, options are very limited. The only best use available for the bulk of material being generated is energy recovery.

We have identified several facilities than can, or could once operational, take these Focus Materials generated in the region and utilise them to generate heat for industrial processes or for power generation.

These facilities are all quite a distance from the ISJO region. The need for significant transport from the region can impact viability on both economic and environmental models. We note that electrification of transport is happening rapidly in many parts of the world. Cheaper transportation costs brought about by electrification and the availability of renewable energy will make transport to distant facilities more feasible.

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1. Introduction

Background

The Illawarra Shoalhaven Joint Organisation (ISJO) is interested in opportunities for the region to progress towards a circular economy. The ISJO wants to minimise the amount of wood panels and related material (the Focus Materials) that go to landfill from businesses located in the region while maximising the regional opportunities for economic gain and employment.

Secondary wood processors, such as frame and truss fabricators, packaging manufacturers, and residential and commercial joineries, consume significant volumes of wood products each year. They also generate significant volumes of waste. Sawn wood offcuts generated by frame and truss fabricators and packaging manufacturers generally have a ready reuse and recycling value.

Waste generated by joineries is problematic because many markets do not accept wood waste for sawn wood offcuts and sawdust.

This project focuses on the waste material from residential and commercial joineries.

The specific Focus Materials are offcuts and dusts of wood panels, including:

- medium density fibreboard (MDF)
- particleboard (PB)
- mixed sawdust.

Project Objectives

The objectives of this research project are:

1. Understand the Focus Materials and identify opportunities for them.
2. Set out the business relations, logistics, systems, and other needs required to implement the opportunities identified.

Methodology

We carried out the following methodology:

Held an initial planning meeting with ISJO
We discussed a detailed project plan and ISJO shared information that had been gathered.

Consulted industry groups
We consulted with:

- relevant manufacturing industry contacts
- generators to understand form and type of Focus Materials, and to gather samples for analysis
- potential aggregators, including panel suppliers and resource recovery facilities.

Prepared and analysed samples
We discussed relevant test methods with laboratory staff and prepared samples for analysis.

Researched the feasibility of our recommendations
We carried out detailed desktop research on possible end uses for the focus materials and the technical requirements, regulatory requirements, market demand and relevant standards for each end use.

We then assessed the test results and compared with technical requirements for relevant end uses.

To make sure pathways are practical and costs are accurate, we consulted manufacturers, generators of Focus Materials, panel suppliers, and aggregators on our recommended pathways.

Drafted the report
We drafted the report and incorporated feedback on the draft into the final version.

Carried out quality assurance
The draft and final report have been thoroughly reviewed for spelling, grammar, readability, and relevance to the RFQ objectives by a thinkstep-anz staff member who was not involved with the project.

Circular economy

Circular economy principles have informed the research methodology. A circular economy is an alternative to the traditional linear economy model of make, use, dispose (Otter 2018).

In a circular economy, waste and pollution are designed out, products and materials remain in use at their highest value, natural systems are regenerated (UK WRAP 2019). The model also includes a shift towards renewable energy and away from linear, fossil fuel-based alternatives.

An intrinsic feature of the circular economy model is the separation of biological (renewable) resources from technical (finite) resources. The circular economy system diagram in Figure 1 (Ellen MacArthur Foundation 2020) represents the continuous flow of biological and technical resources envisaged by the circular economy.

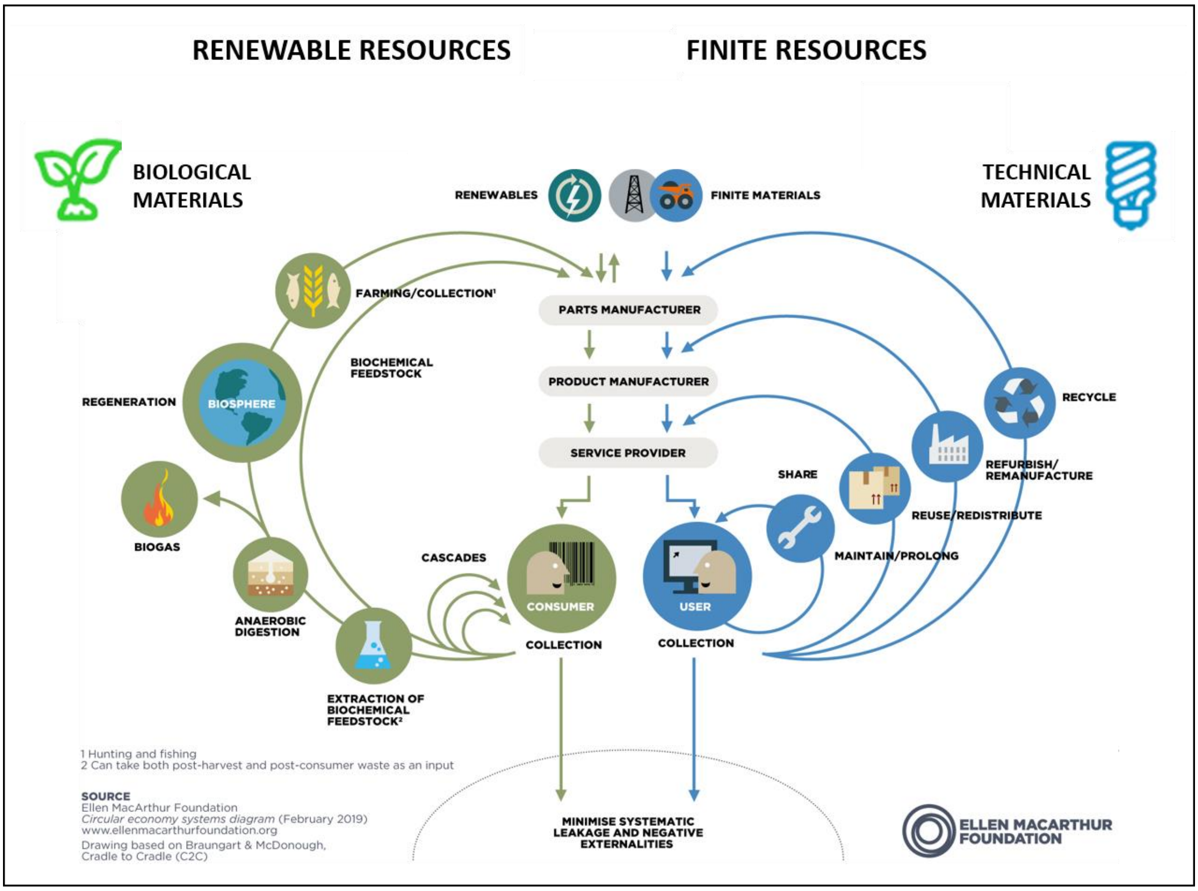


Figure 1: Circular economy flow of resources (Ellen MacArthur Foundation 2020)

The separation of biological and technical material cycles is an important feature of the circular economy system. The separation helps avoid contamination of one type of material with the other, which would otherwise reduce the material's economic or regenerative value.

It is important to point out that the circular economy is:

- a scale – everything has a 'degree' of circularity. While multiple methods exist for quantifying how circular a product or business is, the most widely adopted is the Material Circularity Indicator (MCI), developed by the Ellen MacArthur Foundation. The MCI methodology captures multiple means of achieving circularity. It quantifies circularity on a scale between 0 and 1, where 0 is entirely linear, and 1 is perfectly circular
- not new – the timber industry has been using residues and by-products to produce other products, energy, and chemicals for decades (if not centuries).

Timber, wood, and paper products use significant amounts of bioenergy, and many products can be reused, recycled, or used for energy at end-of-life. Forest and wood products are very much part of the bioeconomy.

The increased use of adhesives, coatings, and preservatives made from fossil-based finite resources on wood products mixes the biological materials cycle and the technical materials cycle, introducing the types of cross-contamination that the circular economy tries to avoid.

It is also important to note that while the definition and principles of the circular economy are generally agreed upon, they are interpreted widely by different people.

The World Business Council for Sustainable Development has recently released a CEO Guide to the Circular Bioeconomy (WBCSD 2019). The Guide, authored by Boston Consulting Group, estimates the potential economic opportunity of a circular bioeconomy for products, energy, food, and feed in 2030 to be USD $7.7 trillion.

The Guide identified three areas for the business case for forest-based industries to access this huge economic potential:

1. Access to new markets and customer segments
2. Provide a competitive advantage
3. Mitigate regulatory and societal risks (See Figure 2).

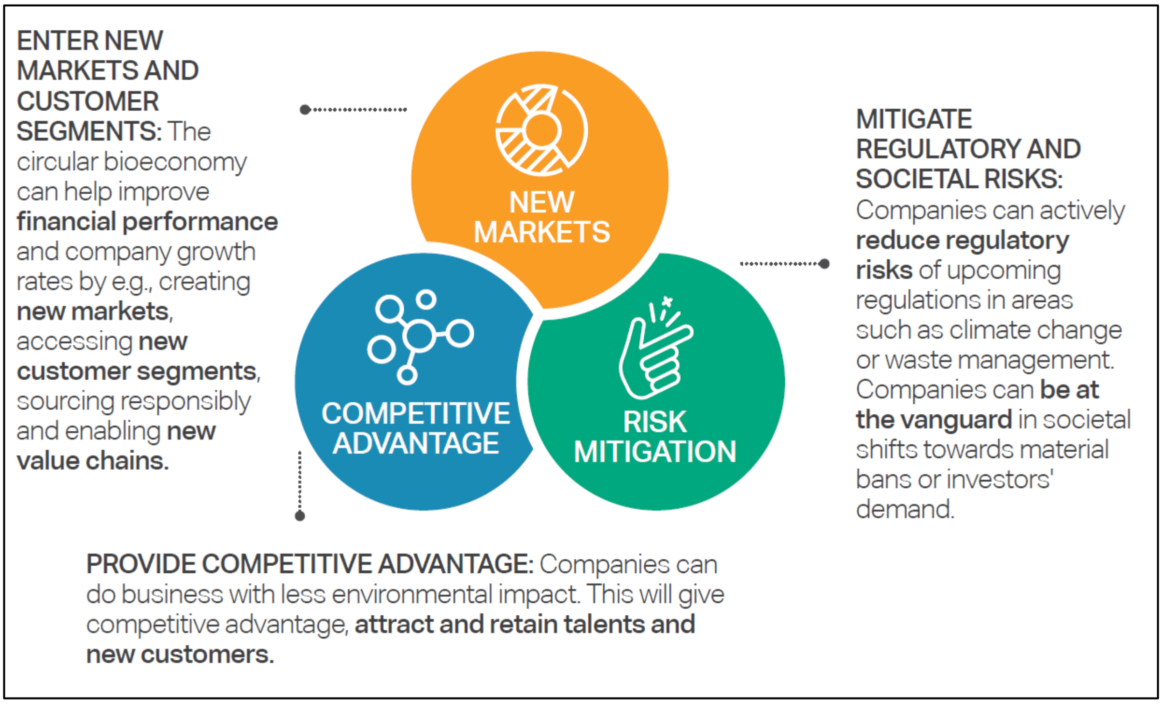


Figure 2: Business Case for Circular Bioeconomy. Source CEO Guide to the Circular Bioeconomy (WBCSD 2019)

In Australia, the current circular economy focus has often been more on increasing the viability and coverage of the recycling industry, creating jobs, and in some cases, also reducing greenhouse gas emissions. For example, the South Australia circular economy approach plans to deliver an additional 25,700 full-time equivalent jobs by 2030 and reduce greenhouse gas emissions by 27% or 7.7 million tonnes of CO_2 equivalents.

There is a significant opportunity for Australia to benefit from closer examination of higher order technical circular economy solutions, such as reuse and remanufacture, as well as biological solutions such as composting to restore carbonaceous material back into the biological cycle.

Timber and the circular economy

In the circular economy model, there is a distinct hierarchy for the recovery of materials. The best practice hierarchy for timber and wood products is illustrated in Figure 3. The top five levels in the hierarchy belong to the circular economy and are listed in descending order of circularity. The last four levels belong to the linear economy, as they are not returning resources back for productive use.

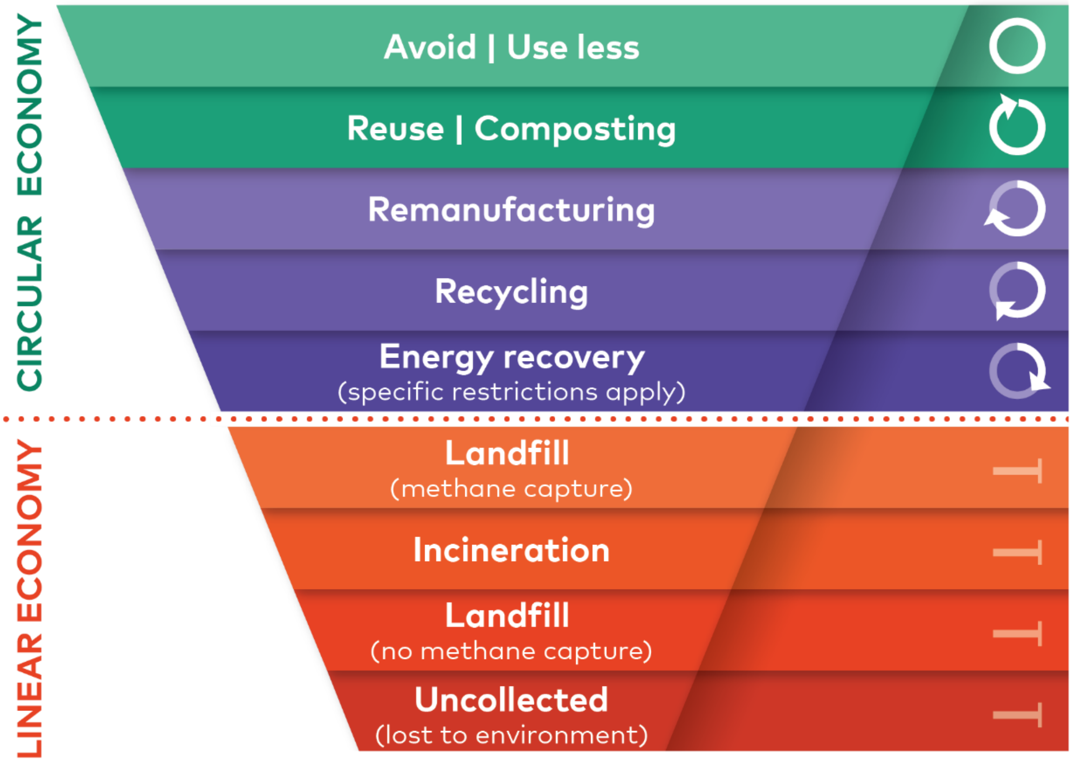


Figure 3: Best practice hierarchy for timber and wood products

Avoid, use less

In any consideration of resource use, the first and best option is always to not use resources in the first place. To avoid the use of resources through finding alternatives, or using less by smarter design avoids the need to address conservation of resources for future use.

The economic value of avoidance is demonstrated as we find new options to extract greater value from resources already in use rather than using new materials for that purpose.

Reuse, composting

The highest value in the circular economy is awarded to materials that are completely circular – which are returned in a useful state as either reuse, or in the case of biological materials, as compost to return the carbon back into the biological cycle.

The composting of used materials is considered equivalent to reuse, so long as the materials are not contaminated and are made biologically available (i.e., not buried). Composted materials made from recycled organics in NSW must comply with the compost resource recovery order. They may also comply with Australian Standard *AS 4454 Composts, soil conditioners and mulches* to be able to claim a benefit to the user of the product.

It is clear from the work of the Ellen MacArthur Foundation and their partners in the MCI methodology that the use of regeneratively sourced biological materials is equivalent to the re-use of technical materials in terms of its circularity. Regenerative sourcing uses the regenerative concept found in, for example, Forest Stewardship Council (FSC) certification. The carbon extracted from the forest is no greater than its capacity to regenerate that carbon in biological materials.

There are not any sustainable production standards (including FSC or Programme for Endorsement of Forest Certification (PEFC)) that totally align with the regenerative production requirement of the circular economy yet – this is an area in which we anticipate an evolution of standards moving forwards.

Remanufacturing

Remanufacturing takes a used product and returns it to an as-new state through manufacturing processes. It requires intervention to achieve a fit-for-purpose state, compared to reuse, which does not.

Recycling

Recycling is a well-known and practiced method of taking constituent materials from a product and processing them into brand new products. Ideally this process will return the materials to a state of at least the same value.

Where a material of higher value can be created, this is known as upcycling, and is the most preferable (and circular) form of recycling.

Where the materials are used at a state of lesser value, this is known as downcycling. This should be avoided where possible, as downcycled product is a less circular solution.

Energy recovery

Energy recovery is the least preferred option from the perspective of the circular economy and can only be considered marginally circular for biological materials.

There are limitations which restrict the use of energy recovery as a circular option. All the following restrictions apply:

- the materials have been regeneratively sourced in the first place
- all other circular economy options have been exhausted
- the energy recovered is both maximised and displaces the use of fossil fuels.

Linear options

All remaining options belong to the linear economy – they do not return the material back into a biological or technical cycle for productive use, and instead represent resources that are lost to the economy. These options, in order of preferability, are:

- Landfill with methane capture – the wood products are placed in a landfill where any carbon that is released as methane is captured and productively used. A potentially significant proportion of the carbon in the products can remain ‘locked’ in the landfilled components and not enter the atmosphere.
- Incineration – this returns all of the carbon in the products to the atmosphere without the energy released being put to productive use. It avoids the potential for methane release, along with its high greenhouse impacts compared to carbon dioxide.
- Landfill without methane capture – the lowest level of responsibility in the hierarchy. This allows methane release and the associated negative greenhouse gas impact from the anaerobic degradation of the materials over time. The methane released is likely to have a larger negative impact than the potential for ‘locked up’ carbon benefit in what remains.
- Uncollected materials – those which remain exposed to the elements and will decompose over time to a mix of carbon dioxide and methane, with little to no carbon returned to the biological cycle.

Evaluating circular economy options

When deciding the merit of circular economy options, these must be considered within a life cycle context, rather than a narrow focus on the specific solution at hand. Issues to consider include:

- Useability of the product – will the product be able to be used for the intended application? What are the limiting factors that need to be evaluated?

- Contaminants – will contaminants such as resins restrict the usefulness of the product?
- Transport to the recycler and the user – how far does it need to travel, and by what means? Is the carbon impact from transport large enough to negate the benefits of circularity? Can fossil fuel-based transport be replaced with electrified transport that is powered by renewables?
- Composting benefits – is the value of the material to be composted limited by insufficient biological availability, such that it becomes another form of landfill?
- Regulatory limitations – are there regulatory requirements that limit the ability of certain solutions to be implemented, such as air emissions limits or restrictions on the use of thermally treated materials?

Regulatory context

When examining options for circularity of materials, there are regulatory limitations that apply to how certain wastes may be processed.

In New South Wales, resource recovery orders (RROs) and resource recovery exemptions (RREs) allow some wastes to be beneficially and safely re-used – independent of the usual NSW laws that control using waste (NSW EPA 2020a).

This applies to using waste in connection with:

- a process of thermal treatment
- applying waste to land
- using waste as a fuel.

The framework for RROs can also apply to a named person and RRE for use by everyone (NSW EPA 2020b). The named orders themselves are confidential to the specifically named person so are not available for the public to see. The exemptions are regularly published in the NSW Government Gazette and apply to anyone using the recovered waste covered by the order.

Potential solutions for products which qualify as thermally treated must comply with the requirements for RROs and RREs.

2. Quantifying and characterisation

Quantification

We estimated the waste flows from joinery businesses using the latest available annual consumption figures for 2016-17 for particleboard and MDF from the Australian Forest and Wood Product Statistics (ABARES 2018).

We then applied consumption for the ISJO region on a per capita basis (ABS 2017), assuming business in the region supplied 100 percent of regional demand. Joineries also produce products for other New South Wales regions with some joineries supplying Sydney CBD and southern LGAs including Sutherland Shire. Others were supplying builders working on projects in Canberra, and even Newcastle.

As some of the joineries we interviewed noted, land and labour costs are significantly lower in the region compared to Sydney. Transport connections to many parts of Sydney are quicker (and cheaper) from the Illawarra than supply by manufacturers in western Sydney. Joineries also use a small volume of plywood and sawn timber for some projects.

We estimate that joineries in the ISJO region generate around 5,031 tonnes of Focus Materials per annum – see Table 1. These figures exclude any waste generated by the consumption of plywood and timber.

Material generated from joineries

Even though computer-aided design packages endeavour to get the greatest number of useable pieces out of each panel and many kitchen cabinets are manufactured to standard sizes, there is still substantial waste. The industry sources we spoke to estimate this waste material generated from joineries to be in the order of 20 percent of consumption.

We developed compositional data based on data provided by a small number of the larger joineries and kitchen manufacturers in the region. Based on this limited data, we calculated approximately 12 percent of the combined waste is generated by manufacturers as sawdust. This equates to 604 tonnes per annum across the region. See Table 2.

Consumption	Units	Particleboard	MDF	Total
Australia-wide consumption	*tonnes per annum*	715,412	449,082	1,164,495
ISJO region estimated consumption	*tonnes per annum*	15,453	9,700	25,153
Waste (estimated 20%)	***tonnes per annum***	**3,091**	**1,940**	**5,031**
Ratio of consumption	*%*	61%	39%	100%

Table 1: Total waste ISJO consumption and estimate joinery waste generation. Source: ABARES (2018) and industry estimate.

	Particleboard	MDF	TOTAL (tonnes)
Offcuts	2,720	1,707	**4,427**
Sawdust	371	233	**604**
TOTAL	**3,091**	**1,940**	**5,031**

Table 2: Estimate of focus materials generated by joineries in the ISJO region 2018/19

End-of-life material

We identified a significant volume of the Focus Materials in end-of-life waste. Most of this waste originates from replacing an old kitchen or bathroom cabinetry as part of renovations. As part of their contracts, most kitchen manufacturers will remove kitchens they are replacing and dispose of these at local landfills.

Some clients will undertake the removal themselves and dispose of these. If they are in good condition, are often sold via Gumtree/eBay or local networks as complete second-hand kitchens. Some are transported directly to a resource recovery or waste disposal centre via council bulk waste clean-ups.

The manufacturers who we interviewed stated that reuse of kitchen cabinets is rare. The uninstalled kitchens are often destroyed during demolition and taken to waste disposal facilities near the point of installation or the manufacturer – via Whytes Gully, Benedict Recycling, or Bingo Waste for manufacturers located in Unanderra.

The Housing Industry Association (HIA) estimated that there were 149,342 kitchen renovations and 233,188 bathroom renovations across Australia in 2018/19. We have estimated that 2,566 tonnes of end-of-life cabinets are generated in the ISJO region each year. This is based on 1 cubic metre of MDF and particleboard per kitchen renovation and 0.1 cubic metre for each bathroom renovation, at an average density for particleboard and MDF panels of 688kg/m^3 (FWPA 2017a, FWPA 2017b). See Table 3.

End-of-life item	TOTAL (tonnes)
Kitchen cabinets	2,220
Bathroom cabinets	347
TOTAL	**2,566**

Table 3: Estimate of end-of-life kitchen and bathroom cabinets generated in ISJO region 2018/19.

Note: These estimates include imports of cabinets from flatpack kitchens which are increasingly common.

Form of Focus Materials

Although the form of the Focus Materials has a bearing on potential alternative uses, both the material generated from joineries and end-of-life materials are regarded as post-consumer wastes (AS 14021:2018).

Material generated from joineries

- Particleboard offcuts – raw board and melamine or other laminate
- MDF offcuts – raw board and melamine or other laminate
- Sawn timber offcuts
- Sawdust – mixed timber/PB/MDF – with and without edge tape trimmings.

These various forms are illustrated in Figure 4 below.

Sawdust is a mixture of the material that is cut, shaped, and trimmed. Dust collection is a necessity in wood processing businesses and is a considerable expense to install and operate. Most of the joineries we visited had a single dust collection system that dumped sawdust into one receptacle. One large joinery had two dust collection systems that collected sawdust from different machines.

Dust is collected into separate waste bins which are very challenging to load into front lift waste collection vehicles. For this reason, some waste cartage businesses refuse to accept sawdust in this form and require the bagging of all sawdust.

Melamine coated particleboard offcuts

Sawn timber offcuts

Joinery sawdust collection system

Mixed raw, melamine and laminated particleboard and MDF

Figure 4: Forms of joinery generated focus materials in the ISJO region

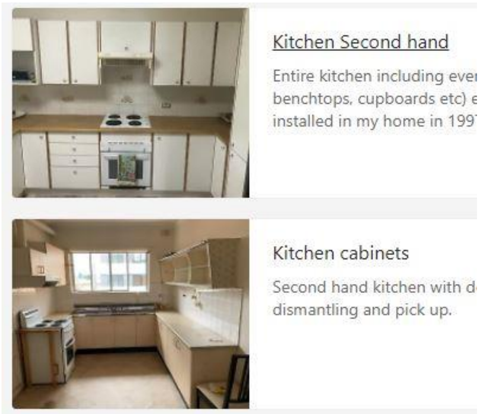
End-of-life Focus Material

- Dismantled/second-hand kitchen cabinets, drawers, and doors.
- Dismantled/second-hand joinery items.

These various forms are illustrated in Figure 5 below.

Illegally dumped kitchen cabinets. Image Tweed Shire Council

Illegally dumped joinery/furniture items. Image: Shoalhaven City Council



Second-hand kitchen cabinets advertised on Gumtree

Dismantled kitchen cupboard with drawers.

Figure 5: Forms of end-of-life Focus Materials

Key ingredients of PB and MDF

Particleboard (PB) and Medium Density Fibreboard (MDF) are composite materials comprised mainly of wood or wood fibre. Australian producers of these products largely source the wood and wood fibre from softwood plantations that are sustainably managed and certified against PEFC and/or FSC forest management standards.

PB is manufactured from wood particles or flakes

PB is a reconstituted wood panel product manufactured from wood particles or flakes. A mat of individual wood particles (virgin or recycled) is coated in adhesive resin and pressed together into a finished panel. As the wood fibres in the particles are randomly oriented, the finished panel has uniform properties in each direction (WoodSolutions 2020a).

PB is used for different internal applications, depending on the grading of the material. Common applications include furniture, veneer substrates, and base panels for cupboards. Structural grade particleboard is primarily used for internal flooring.

MDF is manufactured from wood fibres

MDF is also 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. MDF is smooth on both sides (WoodSolutions 2020b) and

produced as wood sheets in varying widths and lengths. Bonding of wood fibres within MDF relies on synthetic resins and thermosetting adhesives, cured under heat and pressure. MDF is primarily used for internal applications and is available in raw form with a fine sanded surface or with decorative overlay such as wood veneer, melamine paper, laminates, or finished with polyurethane.

Resins are used to make PB and MDF

The dominant types of resins used in the manufacture of PB and MDF are:

- urea formaldehyde (UF)
- melamine-urea formaldehyde (MUF)
- melamine-formaldehyde (MF).

UF resin is a good, cost-effective adhesive, making it the most common option. UF, MUF, and MF adhesives are all light or milky coloured when cured. Melamine is a more durable and water-resistant component in resins. It also reduces formaldehyde emissions.

Currently, all board that is manufactured in Australia comply with E0 or E1 emissions limits. E0 and E1 panels are rated at Low Formaldehyde Emitting according to Australian Standards.

The total resin content varies with MDF having a slightly higher resin content than PB. Other ingredients include decorative paper and small volumes of paraffin wax for added moisture resistance. See Table 4.

Ingredient	Proportion (by weight)
Wood particles or fibres from plantation softwoods (including water)	>80%
Melamine/Urea/Formaldehyde Resin	<20%
Decorative paper	<2%
Paraffin wax	<1%

Table 4: General composition of new MDF and PB

Chemical characterisation of the Focus Materials

We sampled and analysed sawdust from several joineries' cutting processes to chemically characterise the Focus Materials and determine their suitability for several circular economy applications.

One sample was collected from each of five of the largest joineries in the ISJO region and sent for analysis at SESL, a NATA accredited laboratory. The samples are shown in Figure 6 and were a mix of sawdust from sawn timber, PB and MDF.

Figure 6: Joinery sawdust samples ready for analysis

Table 5 outlines the average results for each of the five samples, together with a comparative analysis of virgin sawn softwood pine. See Appendix 4 for detailed results.

General observations

Analysis results and implications for recycling are discussed in more detail in the relevant sections below however some general observations can be made. Chemical contamination appeared very low, and results did not indicate any particular concerns. For example, analysis for most metals, including arsenic, chromium, lead, and copper was below limits of quantification (LOQ) for the analysis method. The only metal detected above LOQ in the samples was manganese, which occurred at the levels typically detected naturally in wood and is not significant.

Low pH values

pH levels were low – averaging 5.2 and ranging from 4.9 to 5.4. Radiata pine is the most common softwood used to manufacture MDF and particleboard in Australia and has a natural pH of typically 4.0 to 4.8 (Nyugen CSIRO 2005). Spotted gum is the most common hardwood species cut for timber on the New South Wales (NSW) south coast and has a pH of around 4.5 (Nyugen CSIRO 2005).

Substance	Unit	Virgin sawn softwood pine	Focus materials (joinery sawdust)
		mean or range	mean
Antimony	mg/kg	<5	<5
Arsenic	mg/kg	<5	<5
Beryllium	mg/kg	<1	<1
Boron	mg/kg	<3	<3
Cadmium	mg/kg	<1	<1
Chromium	mg/kg	<2	<2
Cobalt	mg/kg	<1	<1
Copper	mg/kg	<5	<5
Lead	mg/kg	<5	<5
Manganese	mg/kg	15-188	27
Mercury	mg/kg	<0.1	<0.1
Molybdenum	mg/kg	<1	<1
Nickel	mg/kg	<2	<2
Selenium	mg/kg	<5	<5
Tin	mg/kg	<5	<5
Vanadium	mg/kg	<5	<5
Zinc	mg/kg	1-69	14.02
Total Sulphur	mg/kg	0.01	0.03
Air Dried Moisture	% as received	11.9	4.1
Ash	% as received	0.2	0.9
Calorific Value (gross)	mg/kg	16.74	19.29
Moisture content	% as received	12	6
pH (1:5) in water	pH units	4.0-4.8	5.2
Electrical Conductivity (1:5)	dS/m	NA	0.48
Phosphorus (P) - Total	% dry wt	7-50	0.01
Nitrogen (N) - Total	% dry wt	0.8 (stem) 3.1 (bark)	3.78
Wettability	min	NA	5.80
Glass, metal, rigid plastics	% Retained	<0.01	<0.01
Light plastic >5mm	% Retained	<0.01	<0.01
Stones & lumps of clay ≥5mm	% Retained	<0.01	<0.01

Table 5: Mean results for five sawdust samples taken from larger ISJO joineries vs virgin sawn softwood pine.

High nitrogen levels

Nitrogen levels are high – significantly greater than the minimum 0.8% required in Australian Standard *AS 4454 Composts, soil conditioners, and mulches* to claim a benefit to the user of the product. However, the benefits of this nitrogen content for the growth of plants would require a separate investigation.

The result reflects the high proportion of nitrogen in the resins used. Urea formaldehyde is approximately 35% nitrogen (Dunky 1998), and melamine formaldehyde is approximately 66% (Suchy *et al.* 2006).

The benefits of nitrogen content for biological systems depend heavily on bioavailability rather than just content. While nitrogen content in melamine may be high, it is not readily available to biological species (at least not initially) due to the stability of melamine resins.

We recommend further research into the focus materials' nitrogen characteristics and their availability over time for biological species.

Edge tape contamination

The presence of visible foreign contaminants such as edge tape (which is mostly white in colour) was lower than expected. Edge tape trimmings are very visible in some of the samples yet when analysed were below the limit in *AS 4454*, except for one sample (#6). This meets the standard however the edge tapes obvious presence could be an issue if this material were visible in a final compost product.

Two samples were collected from one joinery – one of which had a very high proportion of edge tape. This sample (#6) was only analysed for foreign contaminants (i.e., plastic >2mm) in line with Australian Standard *AS 4454:2012 Composts, soil conditioners and mulches.* This much edge tape would definitely be an issue as this material would be visible in any finished compost product.

Wettability results higher than standard for compost

A negative result from a composting perspective is the wettability result. Wettability is a measure of the how easily compost can be re-wet once it has dried out. Some materials can repel water when they are dry and be difficult to re-wet (Compost for Soils 2011). Input materials that are hydrophobic (water repelling) are not great compost inputs.

Wettability is measured by the time it takes for water to absorb into the material (under strict testing conditions). Compost requires a wettability of less than 5 minutes. Apart from the sample with a high proportion of sawn timber (sample #4) all samples tested a minimum value of 7 minutes.

There is no maximum value of wettability for raw mulch or pasteurised garden organics.

Moisture resistance (or lack of wettability) is a desirable characteristic for the purpose of the original material (which will be used in kitchens and bathrooms where it will be exposed to moisture). However, it is not desirable at end-of-life from a compostability perspective. We recommend that any trials for land application examine this characteristic and the change over time due to exposure to the elements and the composting process in more detail.

Effect on soil biota

Analysis of the effect of the focus materials on soil biota (micro-organisms including fungi and animals including worms) was outside the scope of this project.

High energy content

From an energy recovery perspective, the gross calorific value is high, averaging 19.2MJ/kg. This is expected given the resin content and low moisture content. Ash content is very low at 0.9%. Both findings are very positive from the perspective of this end-of-life option.

Research is needed prior to use in compost products

Overall, our chemical analysis suggests that the Focus Materials might make for useful compost product inputs but that wettability, impacts (positive or negative) on soil biota, and the availability of nitrogen from resins for plant growth requires further research. Some international research exists, which is documented later in this report.

Besides direct reuse, composting of the Focus Materials would be the preferred option from the perspective of circularity – everything else being equal.

3. Business and economic opportunities

The following opportunity areas were researched and explored during the project:

- Reuse of offcuts
- Recycling into new building products
- Recycling into land applications
- Thermal energy for industrial processes

Reuse of offcuts

Internal reuse of offcuts within a joinery/kitchen manufacturer is common. It makes economic sense for business (and facilitates a circular economy). Larger offcuts are reused immediately within the manufacturing process. Several joineries that we interviewed set larger offcuts aside until the completion of a job. If unused, these offcuts are often discarded after 3-6 months to free up space within the factory. Smaller offcuts are often collected (see Figure 7) and transported to site for installers to pack out uneven surfaces.

Figure 3: Offcuts set aside for reuse

Recycling into new building products

Material recovery through the recycling of waste wood is important for wood-based industries. The most common wood-based materials are:

- Particleboard (often called chipboard)
- High, medium, and low-density fibreboard (HDF, MDF and LDF)
- Oriented strand board (OSB)
- Wood-plastic composites (WPC)

New particleboard panel products

The big circular economy opportunity for particleboard offcuts in the ISJO region is collecting and recovering raw and melamine coated offcuts for production of new particleboard panels or other particle-based products. This closed-loop recycling is common in many European countries where fibre-sources are limited. It is estimated that up to 79% of particleboard inputs in Italy are waste wood. (BAV, 2015). See Table 6 for estimates for Italy and other European countries.

Country	Proportion of panel input that is waste wood
Italy	79%
Great Britain	56%
France	35%
Spain	33%
Germany	20%
Austria	0%

Table 6: Proportion of waste wood as input into particleboard panel production. Source BAV 2015.

The particleboard production process lends itself to using recovered wood, as it typically has a low moisture content compared to virgin wood from forests or plantations. Using recovered wood with a lower moisture content means that less energy is needed to achieve the 4% moisture content flaked wood needs at the start of the production process. Lower energy needs mean less wood-based and natural gas fuel is needed – making economic savings and reducing greenhouse gas emissions at the production facility.

A wood recycling service has recently been introduced by reDirect Recycling – a company wholly owned by Borg Group (Borg). Borg manufactures new MDF and particleboard panels at their Borg Panel manufacturing facility at Oberon in the NSW central tablelands. These are distributed to joineries and kitchen manufacturers under their polytec brand. There is a polytec distribution centre in South Nowra (Figure 8).

Figure 4: Borg/polytec distribution centre located in South Nowra.

Borg obtained permission from NSW EPA to use recovered urban wood residue (UWR), including timber offcuts, pallet waste as well as particleboard offcuts, after a trial period running from September 2019 to September 2020. They are permitted to utilise up to 25% of their wood feedstock needs from UWR. This replaces virgin wood from plantations and equates to a demand of about 125,000 tonnes per annum (V. Bendevski 2020, *pers. comm.* 01 November 2020).

All joineries we interviewed are clients of Borg/polytec, and all expressed an interest in any particleboard takeback scheme, provided the price was competitive with their current disposal services. When asked whether they would be prepared to separate particleboard offcuts from MDF offcuts they said this would not be a problem.

To facilitate their sourcing of all types of UWR, Borg have started a wood recycling company reDirect Recycling (reDirect). reDirect have purchased an existing wood recovery facility in Ingleburn and started developing a new wood resource recovery facility at St Marys. They have recently commenced a trial pickup service for volume polytec clients in Western Sydney. This involves reDirect Recycling supplying a small 2.3 cubic metre front-lift bin and picking it up when notified by the joinery that it is full of particleboard offcuts. See Figure 9. With a nominal charge per lift, a bin tightly packed with offcuts (density = 500kg/m3) should deliver a cost reduction of more than 50% compared with landfill charges. (A Hudson *pers. comm.* October, 2020). Joineries with an online account with polytec can register for the service at https://www.redirectrecycling.com.au/bin-pre-signup/

Figure 5: Borg company reDirect have commenced a particleboard wood recycling service.

In the early days of recovery, one reported downside of PB with high levels of recycled content was higher silica content (from sand or grit from the recovered wood). The high silica content resulted in reports of higher wear and tear levels on sanders, saws, and other joinery equipment (Taylor *et al.* 2010). This problem has been largely addressed by introducing specialised cleaning towers to remove sand, grit and other non-wood impurities from recovered wood before it is introduced into the manufacturing process.

Other particleboard manufacturers

D&R Henderson operates a particleboard manufacturing facility in Benalla, Victoria. They have been taking back offcuts from joineries they supply in Sydney for many years and via their Wetherill Park distribution centre, a practice that continues.

Laminex supply many joineries in the region with particleboard panels. Their nearest raw particleboard manufacturing facility is in Gympie, Queensland. They do source some offcuts from nearby and the Brisbane region, however, the distance to this market would make supply from the ISJO region prohibitively expensive.

Due to market confidentiality, we cannot establish a supply breakdown in the ISJO region from all particleboard manufacturers, including Borg. Of the joineries we visited during the research, Laminex had a higher market share of particleboard sales used to manufacture cabinet carcasses. However, all joineries reported increasing Borg particleboard purchases for cabinet carcasses in place of Laminex particleboard product. This trend is likely to continue in the region as Laminex no longer have a distribution centre in the region, and Borg are targeting that market segment. Therefore, it is likely in the future that much of the joinery generated particleboard could be taken back to Borg when reverse logistics are established in the region.

Pallet blocks

Composite pallet blocks are used to construct transport pallets, including Europallets, which are the standard European pallet size. Around 450 – 500 million are currently in circulation (Fisher's Pallets 2020). Fisher's Pallets in Victoria are the only producer of Europallets in Australia and produce mainly for companies exporting their goods to Europe.

In Europe, manufacturers of pallet blocks utilise significant volumes of waste wood instead of virgin wood - see Ecoblock with one production facility in Italy (Ecoblok 2020) and EuroBlock with four production sites in Germany (Euroblock 2020).

There is currently no Australian manufacturer of pallet blocks. However, one New South Wales company was considering doing so and planned to utilise joinery generated and end-of-life wood. These discussions were commercial-in-confidence. As it is a simple extrusion process used to produce pallet blocks, the quality requirements for recovered wood are likely to be lower than those required to produce new particleboard. Some MDF may be able to be utilised.

Wood-plastic composites (WPC)

Wood-plastic composites are made by combining wood fibre or flour (very finely ground wood) with thermo-set plastics and other additives. This material is then heated and formed into the required profiles. There are restrictions on timber species that can be used because of incompatibilities with the natural oils and resins in some species and the WPC production process. (Taylor et al., 2011).

WPC is manufactured in Australia in Melbourne by Modwood and in Adelaide by Advanced Plastic Recyclers (APR 2020). Modwood utilises pre-consumer reclaimed wood from radiata pine plantations (Modwood 2020). APR claim to use 100% post-consumer wood. The distance from the ISJO region precluded further investigation.

The benefits of wood-plastic composites as part of the circular economy remain to be determined. There is an argument that, unless wood plastic composites can also be recycled effectively, what is being created is a hybrid material that sequesters biological materials in an inaccessible way. If so, this is not a robust circular solution as it does not avoid waste as much as postpone or indeed assure it.

Cement-based products

Fibre cement board is a composite material made of Portland cement, sand, and cellulose fibres. Sydney-based manufacturer, James Hardie source all their fibre from radiata pine plantations. Following extensive research (R. Coutts 2005), from 1981 natural fibre replaced asbestos in these types of products in Australia.

It is unlikely that particleboard or other Focus Materials would be suitable for this process, however, MDF offcuts could conceivably by broken into component fibres and utilised in a cement fibre building product, as per the MDF recovery process invented in the United Kingdom currently moving towards commercialisation (MDF Recovery 2020). The cost of doing this would very likely exceed the cost of purchasing new wood fibre and require extensive research and testing over a long period.

Timbercrete is a blend of cellulose, cement, sand and binders, and other materials into a building block (Timbercrete 2020). The source of cellulose is recovered wood. We contacted the supplier of recovered wood to TimberCrete, and they confirmed they supply all the company's needs.

Regarding the contribution of cellulose cement hybrids as a circular solution, offcuts of these materials are being utilised at Boral Cement Berrima where the cellulose content contributes energy, and the cement and sand content is incorporated into clinker.

Recycling into land applied products

This group of products includes:

- Land applied products including animal bedding/chicken litter
- Use in composted products and/or potting mixes

Animal bedding/poultry litter

Recovered wood products are used today in animal bedding products.
There is significant demand for suitable litter for animals, including poultry grown for meat (chickens/broilers, ducks, and turkeys), pigs, pets, and horses in NSW. Broiler farms are located throughout NSW – see Figure 10.

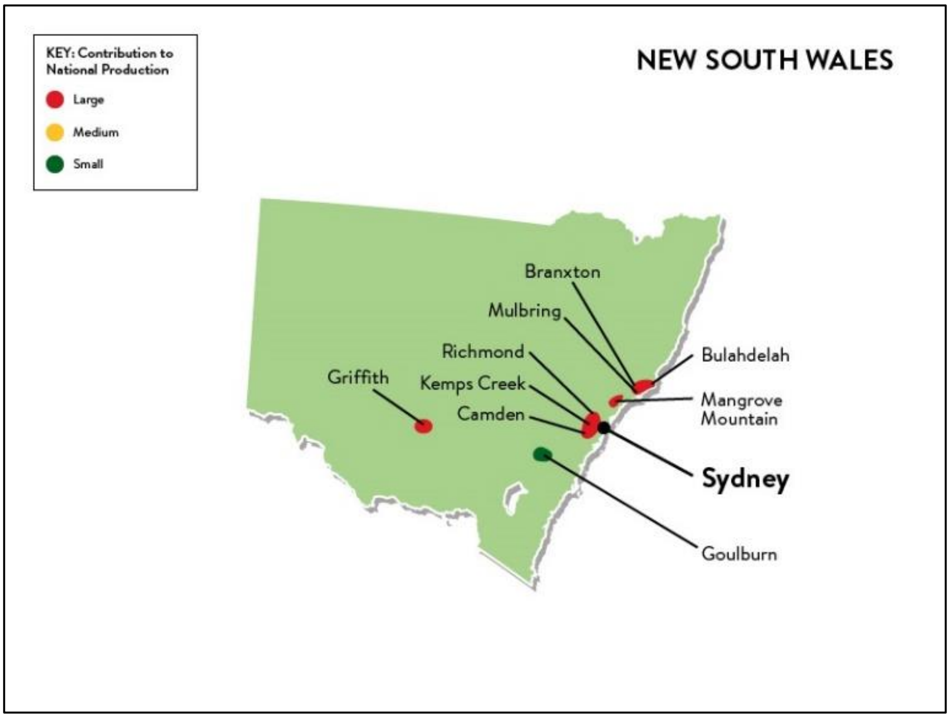


Figure 6: Location of chicken broiler growers in NSW. Source: ACMF 2020.

If used as bedding or litter, these materials will inevitably enter the biological cycle as manure and applied to land or incorporated into other land applied products.

One company, reDirect Recycling at Ingleburn, has a NSW EPA approved resource recovery order and exemption which allows up to 5% (w/w) of engineered wood products and offcuts of blue pine (a softwood product which has been surface treated with permethrin or bifenthrin). The resins present must only be urea formaldehyde, melamine formaldehyde, and/or melamine urea formaldehyde for engineered wood products. This restriction was part of the RRO/RRE application process and was nominated by the applicant (S. Mitchell, *pers. comm.* September 2020).

As the resource recovery exemptions apply to users of such waste-derived products, the exemptions are published in the NSW Government Gazette. Direct Pallets RRO titled “The Direct BioMulch exemption May 2018” was published in December 2019 (Gazette NSW No. 166 of 6 December 2019) together with other RROs. These published resource recovery exemptions are a valuable source of industry intelligence for what is permitted for wood and other wastes in NSW.

Input to compost products

The Focus Materials could be utilised as a component in potting mixes. Potting mixes are produced to Australian Standards. There are no potting mix manufacturers located in the ISJO region. Two companies manufacturing in Sydney, Australian Native Landscapes (ANL) and Grange Growing Solutions are the largest potting mix producers in NSW.

ANL has expressed some interest in trialling engineered wood such as waste particleboard and MDF in their composted products, including potting mixes. However, the current environmental regulations (see Section 4) prohibit them from exploring this option. They have expressed interest in further exploration post testing results.

Industrial heat recovery

We investigated the reuse of Focus Materials to provide thermal energy for industrial purposes. Two joineries in ACT/NSW are currently using the focus materials for this purpose and several existing facilities and proposed projects in the ISJO region and within 400km that could very easily use this material to provide thermal energy. The possible reuses are discussed below in terms of onsite and offsite applications.

Onsite – Joinery heating

During the research phase, we came across a supplier of modern wood heating appliances manufactured by Talbotts in the United Kingdom. The burning of wood waste is very common in Europe and the United Kingdom (UK) – mainly to provide factory space heating and wood waste disposal.

The UK encourages businesses to install technology to provide heat generated by largely renewable sources in the form of non-domestic Renewable Heat Incentives (RHIs). The non-domestic RHI programme recognises wood waste generated by joineries as eligible for the incentive (ofgem 2020).

Talbotts' appliances are sold locally by Wood Tech Group, which provides machinery sales and service to joineries throughout Australia, including the ISJO region. One joinery in NSW has installed a Talbotts wood waste heater supplied by Wood Tech Group. This installation is pictured in Figure 11 below.

Figure 7: Installation of a Talbotts wood energy heater at a joinery in NSW. Source: Facebook.

According to the Managing Director of the facility, the unit takes care of all their board and sawdust waste, removing the necessity of sending it to landfill and the high costs that entailed. All offcuts are shredded and taken to the unit via the dust extraction system. The unit heats air which provides heating to their workshop in the colder months, eliminating reliance on expensive LPG heaters.

Another advantage the business has identified is reducing worker health and safety risks, as the system is fully contained. There is no need for staff or contractors to remove covers and be exposed to dust and/or handle heavy dust waste bags. A very small amount of residual ash is disposed of as waste.

When heat is not needed within the factory in the summertime, the heat is directed to outside the building. This is effectively an incineration process. For this to be an effective solution environmentally, and to comply with circularity requirements, the heat generated must be put to productive use all year round.

There are no visible smoke emissions from the unit. The business is in an industrial estate, and no complaints have been received from neighbouring businesses. See Figure 12 below.

We note that air emissions from such units must be compliant with NSW air emissions limits. The researcher was not able not to ascertain if the unit meets these requirements.

Figure 8: Dust collection on waste wood heater unit is located at the rear of the premises in an industrial area. Image: Google Maps Street View

The facility estimates the payback time is in the range of 6-8 years (which is greater than the 4-6 years estimated before installation) and waste disposal has been reduced by about 85%.

Another nearby wood product manufacturer with a similar wood waste mix has also installed this technology. We did not come across any of these or similar appliances currently installed in the ISJO region. However, one joinery stated that they were strongly considering this option. Another joinery was also reported to be considering installing this technology however, when contacted they did not wish to elaborate.

Wood Tech Group estimate the capital costs are in the order of $500,000 for equipment, installation, associated shredder, and air handling equipment costs for this technology. Costs for appropriate approval and permits would be additional and could be very substantial.

Offsite uses

Industrial process heat users

Large greenhouses for the production of fruit and vegetables are another potential process heat user. Many are heated to ensure even production year-round and some use wood chips. There is no such greenhouse industry in the Illawarra or Shoalhaven regions. Enriva Pty Ltd is an Australian company supplying heating systems to many horticulture, farming, manufacturing, and mining projects. Some of these are biomass-based project included a greenhouse in Swan Hill Victoria (Enriva 2020). The fuel used is waste redgum chip and almond residues from the local area.

Jutsen Pacific, a Canberra-based company, designs, implements, and services biomass energy boiler systems for thermal energy and the co-generation of electricity (Jutsen Pacific 2020). Jutsen Pacific advise that equipment for burning materials containing plastic resins such as the Focus Materials is significantly more expensive than equipment for burning biomass.

For example, a 1MW thermal unit utilising approximately 2,000 tonnes per year of wood with glues (such as the focus materials) would cost in the order of $1-$1.5 million. For utilising plain wood biomass, the equivalent system would cost approximately $500,000. The price difference is claimed to be due to the additional pollution control equipment required to meet state air quality regulations. (T. Strang, *pers. comm.* 2 December 2020)

The only way for a system such as this to stack up financially is for the waste to have a cost to process it – a company could request a gate fee to accept the Focus Materials (such as a waste company). Alternatively, a company that could utilise the heat with enough waste generated onsite that they would not have to dispose of (and hence avoid the cost of disposal).

<u>Chicken broiler farms</u> were considered potential wood energy users as there are quite a few farms located around Goulburn and western Sydney. Jutsen Pacific advised that in most regions of Australia they have much greater cooling needs than heating needs. This is because chickens generate a lot of heat. Gas heating is more suitable for their intermittent heating needs (T. Strang, *pers. comm.* 2 December 2020).

<u>Timber processers</u> were also considered as Boral Timber operates a sawmill at South Nowra. They recently installed equipment to kiln-dry the hardwood timber. They considered using the processing residues (sawdust) to provide heat, which is common in the timber processing industry. A complication for them using wood processing residue as fuel is that they treated most of their timber with a wood preservative, so the residue also contains this preservative. It took many years for them to obtain permission from the NSW EPA to burn preservative-treated wood. They have installed gas (LPG) burning kiln drying equipment. The simplicity and low maintenance requirements of using gas was another advantage.

<u>Wood pallets</u> used for export of goods must be heated and stamped by licenced heat treatment facilities. A review of the approved list of heat treatment facilities in NSW found no authorised heat treatment facilities in the ISJO LGAs. One approved facility in Minto NSW (Afford Pallets) was contacted to see if they would be interested in changing from gas-based heat treatment to wood waste-based heat system. They were not interested as the gas-based system works perfectly fine for their current needs.

<u>Shinagawa Refractories Australasia</u> was approached about their heat needs. They no longer manufacture refractory bricks onsite so have no need. No other refractory brick supplier in the region manufactures in the region either.

Shoalhaven Starches at Bomaderry - owned by Manildra Group - have nine boilers onsite and use a range of standard fuels onsite - mostly gas and coal. They expressed some interest in utilising the Focus Materials. However, the cost of converting existing boilers to utilise the Focus Materials and the time and expense in obtaining planning approvals and NSW EPA permission did not make it an attractive proposition for them.

Boral Cement at Berrima utilised 20,400 tonnes per annum of wood waste-derived fuel (WWDF), and solid waste-derived fuel (SWDF) in their cement kiln at Berrima in the Southern Highlands in the 2019-2020 financial year up to September 2020 (Boral 2020). They have large supply contracts with three waste processing companies in Sydney: Cleanaway/ResourceCo Joint Venture located in Wetherill Park, Brandowns located Kemps Creek and Veolia. See Figure 13.

Figure 9: Wood waste-derived fuels used at Boral Cement, Berrima.

Steel production

Charcoal has been extensively used in ferrous metallurgy in recent years as it has comparable metallurgical properties to coke and coal. It shows great potential for reducing the production cost of iron and steel, with enhanced quality and reduced greenhouse gas emissions (Zhiwei Peng *et al.* 2019). Charcoal can be produced from any biomass substance.

BlueScope Steel is considering using significant volumes of biomass to convert to biochar via a pyrolysis process to replace coking coal in the steel making process. This would primarily be used to replace coal and reduce fossil-based greenhouse gas emissions (BlueScope, 2020).

In October 2020, BlueScope Steel released a Request for Information for the supply of biomass. This document was released commercial-in-confidence. They are at the information gathering stage, so any information about short term or longer-term demand is highly speculative and subject to change. Parties replying to an expression of interest were requested to provide indicative pricing.

If BlueScope decides to proceed, multiple sources of raw material biomass will likely need to be contracted to supply sufficient volume for their needs. While the joinery-generated Focus Materials are relatively small volume, an advantage of the ISJO focus materials is that they are locally available. This would assist in gaining community acceptance for its use compared to biomass from native forestry harvesting residue (for example). The other advantages are that reliable and consistent in quantity. The chemical analysis results do not indicate any red flags in terms of unacceptable contamination.

Sizing and form will also be very important for handling equipment and the necessary pyrolysis processes. Fine material such as joinery sawdust is unlikely to be acceptable; however, the dry chips of Focus Materials may be acceptable.

Power generation

Sunshine Power International operate the Delta Electricity generation facility at Vales Point on the NSW Central Coast. This facility has utilised up to 20,000 tonnes per annum of biomass – including recycled wood waste – as an alternative fuel co-fired with coal to generate electricity for over a decade (Delta 2020). Their EPL licence (EPL #761 NSW EPA 2020h) has had to be varied to allow this.

The different physical characteristics of biomass compared to coal introduce a range of problems when co-milling in existing milling systems. Woody material is fibrous, whereas existing milling equipment has been designed for coal which is brittle and has a lower moisture content (McEvilly et al. 2011).

Hunter Energy, Redbank has recently released an Expression of Interest (see Figure 14) to supply biomass, including end-of-life, industrial, and other wood waste streams within a radius of 400km from Singleton from mid-2021 (Timber & Forestry enews 2020). Unanderra at 288km and South Nowra at 395km are both within this radius. They are interested in up to 700,000 tonnes per annum (tpa) of biomass with a minimum of 2,000 tpa from any one supplier.

This is a significant volume of biomass. It’s unlikely to be available within 400km unless the price is right to attract wood from other reuses and/or cover additional collection and transport costs. As an indication of price attained by high-quality virgin biomass suppliers, hardwood residue from mid-coast sawmills sells for $16 per cubic metre (J. Halkett, Forestlands Consulting, *pers. comm.* November 2020). At these prices it is unlikely that the project would be viable.

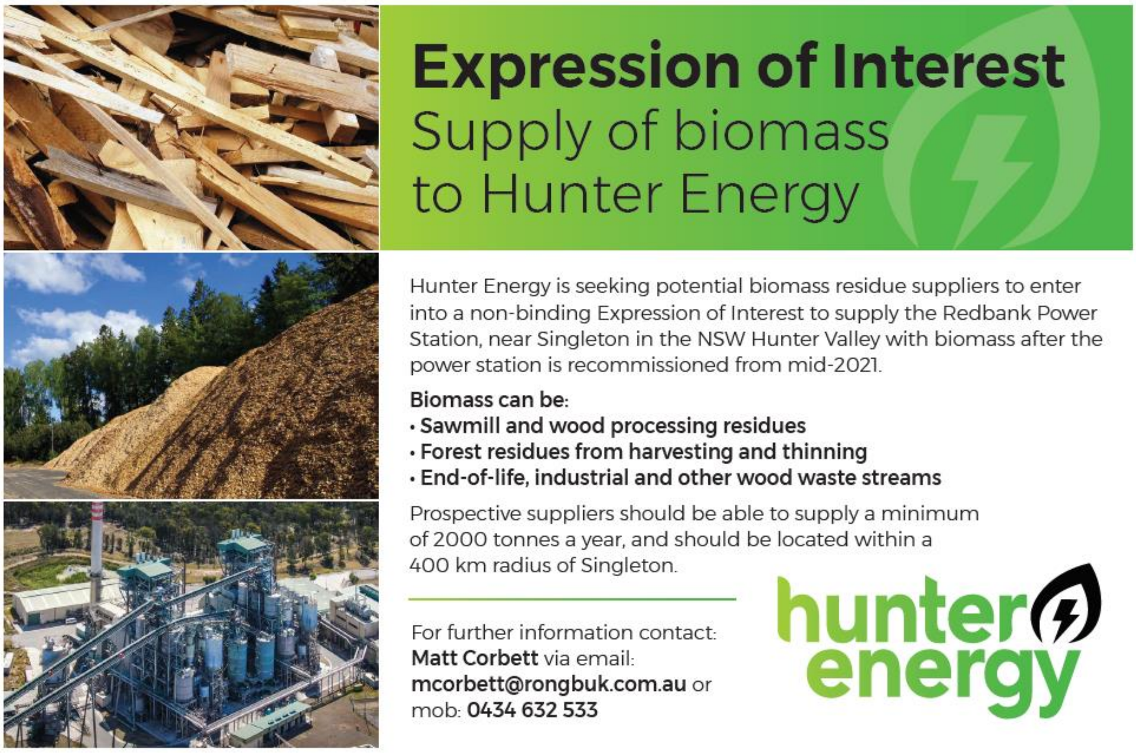


Figure 10: 2020 EoI advertisement for the supply of biomass to Hunter Energy

Borg Manufacturing biomass boiler

Borg Manufacturing at Oberon burns a mix of standard fuels such as forestry processing residues, including bark and non-standard fuels including offcuts of MDF originating at Oberon. They are looking at replacing a significant volume of bark with end-of-life wood products that are not suitable for recycling back into new particleboard. Sawdust would not be suitable due to the type of boiler and the feed-in equipment.

Utilising additional MDF offcuts may be technically possible but is not currently a priority (V. Bendevski *pers. comm.* September 2020).

Other proposals

Waste energy generation and the diversion/capture of useful materials from the waste collection chain and the implementation and rollout of new technologies in this area are expected to be a continued focus and investment area in 2021.

There are several State Significant Projects in the pipeline for energy from waste that are being assessed by the NSW Department of Planning, Industry and Environment. The Department even has a webpage devoted to the topic (DPIE, 2020). It appears to be a matter of time before one is approved, paving the way for more of these projects as landfills continue to be filled.

The Mt Piper Energy Recovery Project is being developed by Energy Australia in collaboration with Re.Group. They are developing a $170 million asset to supplement the current electricity output of Mt Piper Power Station with additional energy created from ‘refuse derived fuel’ (RDF). The RDF is made from non-recyclable household and commercial waste.

This is also a considerable distance from the ISJO region. However, the project is being designed to meet the requirements of the NSW Energy from Waste Policy, so it would be able to accept a diverse range of input fuels. This includes the Focus Materials and even end-of-life cabinets and joinery. It is at an advanced stage along the approval process.

4. Regulatory implications

For the Focus Materials to be utilised in New South Wales, a critical consideration is the waste regulations. In NSW, resource recovery orders (RROs) and resource recovery exemptions (RREs) allow some wastes to be beneficially and safely re-used – independent of the usual NSW laws that control using waste (NSW EPA 2020a).

Particleboard recycling

Using a waste product such as the joinery-sourced Focus Materials in production of new particleboard and many other building products is, in a NSW regulatory context, regarded as using waste in connection with a process of thermal treatment.

In the case of particleboard, this is because, during production, all wood inputs are heated via a drying process to reduce moisture content. Also, wood is mixed with resin and hot pressed during the production process.

As a result, any particleboard maker who wants to use the focus materials to produce new particleboard must apply for a resource recovery order and exemption.

Fortunately, in NSW Borg Manufacturing, the only producer of particleboard in NSW, has an RRO and RRE to utilise some of the Focus Materials (particleboard offcuts) in production of their particleboard at Oberon. They are permitted to utilise up to 25% of their wood feedstock needs from recovered urban wood residue (UWR). This replaces virgin wood from plantations and equates to a demand of about 125,000 tonnes per annum (V. Bendevski 2020, *pers. comm.* November 2020).

Land applications

Using the focus materials in products that could be applied to land such as compost, animal bedding/poultry litter or potting mixes would mean they are subject to the resource recovery framework.

The Focus Materials are defined as engineered wood products (EWPs) by the NSW EPA. EWPs are specifically excluded from the current RROs and RREs for land-applied mulch and compost (NSW EPA 2020c, 2020d, 2020e, 2020f) which have been in place since 2016. The definition of EWPs includes particleboard and fibreboard, such as MDF. See Figure 15.

> **engineered wood products** means engineered, painted, treated or composite wood products such as particleboard, oriented strand board, plywood, laminated veneer lumber, glulam or fibreboard that are manufactured with glues, resins, water repellents, fire retardants, fungal inhibitors and/or other chemicals.

Figure 11: Definition of engineered wood products in resource recovery orders and exemptions for mulch and compost. Source: NSW EPA, 2020b.

With the mulch order, "the EPA recognises that the mulch may contain extremely low and incidental amounts of engineered wood products and/or physical contaminants." Therefore, the order requires "the processor to implement procedures to prevent the presence of engineered wood products and physical contaminants in the mulch. These procedures must be formally documented, and their implementation demonstrated."

Only one named exemption (The Direct BioMulch exemption 2018) allows EWPs in any form. This exemption allows up to 5% (by weight) of EWPs in the BioMulch where only urea formaldehyde, melamine formaldehyde, and melamine urea formaldehyde resins are present. (The Direct BioMulch exemption 2018 - Gazette NSW No 166 pg. 51). The researcher for this ISJO project developed the application to the NSW EPA for this reuse.

The allowance in this exemption indicates that the NSW EPA could be prepared to allow EWPs such as the focus materials, in land-applied products provided that any applicant would have to demonstrate that the proposed re-use:

- is genuine, rather than a means of waste disposal
- is beneficial or fit-for-purpose
- will not cause harm to human health or the environment.

Discussions were held with SoilCo – a major recycler of garden organics in the region who manufacturer a range of soil, compost, and mulch products from NSW EPA licensed facilities in the ISJO region. These facilities are in Nowra (licence #11542) and Kembla Grange (licence #13171). SoilCo are open to recycled inputs in their land applied compost products provided it can be demonstrated that such an input:

- is lawful (under the existing compost or mulch RROs and RREs),
- is beneficial or fit-for-purpose, and
- will not cause harm to human health or the environment.

The benefits of low pH product

Hardwood and/or softwood timber processing residue is one essential input in short supply for recycled (and non-recycled) organics producers. This input is a good source of carbon or body to composted products. Its other desirable property is that it provides a pH lowering effect. The pH of the product made from the composting of garden organics is alkaline. While this is not an issue from a product performance aspect, main markets for recycled organics prefer a pH-neutral product (pH 7.0), so a low pH input is needed as an input.

The pH of hardwood processing residue is around 4.5. The pH of radiata pine (the base species for most particleboard and MDF products manufactured in Australia) is around 4.8 (Nguyen, M. *et al.* 2005).

The Focus Materials have a low pH, as reported in section 2 of this report. If Focus Materials are to be utilised in land-applied products in NSW, the specific exclusion of EWPs in the RRO and RRE for compost and/or mulch would have to be overcome.

The Focus Materials are made with nitrogen-containing resins urea formaldehyde and melamine formaldehyde. Urea-formaldehyde (UF) is the oldest synthetic fertilizer and has been one of the most commonly used slow-release fertilizers worldwide. UF fertilizers are mainly degraded in soil by microbes and decompose to urea and formaldehyde. Urea is used as a nitrogen source by plants, while formaldehyde is generally incorporated immediately into the soil (Ikeda et al. 2014).

Urea formaldehyde

Urea formaldehyde is a resin used widely as a wood adhesive, in textiles, paper, and foundry-sand moulds. It is also used in agriculture as a controlled release source of nitrogen fertilizer (Hayatsu 2014).

Urea formaldehyde's decomposition rate into CO_2 and NH_3 (ammonia) is determined by the action of microbes found naturally in most soils (Hayatsu 2014). The activity of these microbes and therefore the rate of nitrogen release is temperature-dependent. The optimum temperature for microbe activity is approximately 21-32°C (Pietikäinen *et al.* 2005).

There is a range of published research on composting of a range of engineered wood products made with urea formaldehyde.

Keener et al. (1994) composted spent wood fibre pallets bonded with urea-formaldehyde in 200L pilot vessels. Dry matter loss over 14 days was 5.6 percent for the wood-UF with 1 percent urea added. The off-gas from aeration was sampled for emitted ammonia and formaldehyde. No formaldehyde emissions were detected during composting of unamended or urea amended materials. This research did not examine the effect on soil microbes. This would be an important consideration if we look at soil regeneration as part of the circular economy.

Formaldehyde is degradable under aerobic and anaerobic conditions in aqueous and soil. Leungprasert & Otten (2002), cite research (by Adroer et al., 1990; Azachi et al., 1995; Gerike and Gode, 1990; Omil et al., 1999).

ADAS in a series of composting trials used particleboard bonded with urea formaldehyde and found that this was successfully composted (WRAP UK 2007). Urea formaldehyde is used as a slow-release fertiliser. The data show that adding chipboard to garden waste increases the nitrogen concentration and provides additional beneficial nutrients in the form of nitrogen as urea formaldehyde is degraded over time.

The US EPA (2011) funded a pilot study by the University of Tennessee, which concluded that:

- The UF resin in MDF decomposed to harmless end products (carbon dioxide, ammonium, and water).
- Based on air samples collected from above the experimental field plots, there was no evidence of formaldehyde released in the air during MDF decomposition.

- The presence of MDF, in addition to normal soil concentrations of nitrogen, increased the uptake of nitrogen, the corn plants' chlorophyll production, and possibly resulted in an increased corn yield.

Melamine and melamine formaldehyde

While the degradation and befits of urea formaldehyde in chipboard in composted garden organics are well researched and clear there is less certainty regarding composting and degradation of melamine and melamine formaldehyde (WRAP UK 2007). To that end, one of the key recommendations of the ADAS / WRAP UK trial report recommended biodegradation analysis of melamine and melamine formaldehyde in chipboard.

A report on *Slow- and Controlled Release and Stabilized Fertilizers* for the International Fertilizer Industry Association (Trenkel 2010) reported on melamine's use as a source of nitrogen:

> *"Because of its chemical structure, it is very slowly soluble, and it was tested as slow-release N fertilizer by the Tennessee Valley Authority (TVA) in the USA, some decades ago. In the early 1980s, the former Melamine Chemicals Inc. (Louisiana, USA) tentatively developed a urea-melamine fertilizer (Super 60) and carried out some trials on rice to test its delayed nitrogen release ('time release' fertilizer system). However, the results were inconclusive, and the product was never commercialized."*

Trenkel also reported that:

> *"There is no data available about the decomposition of melamine in the soil (hydrolytic decomposition). Melamine is non-hazardous, non-toxic and non-allergic; it has no acute or chronic toxic effects on human health. There is no scientific data demonstrating that the use of melamine as N fertilizer (whether conventional or slow-release) has ever led to toxic effects on animals or men."*

Trenkel also found that there was also no registration for the use of melamine-based fertilizers in Western Europe and reported that USA EPA had banned any use of melamine-based fertilizers. The grounds for this statement on a US EPA ban on any use of melamine-based fertilizers were examined. We could not find evidence of any specific US EPA ban on melamine. However, there was some evidence of imports of fertilizers augmented with melamine to increase nitrogen readings (Government of Canada 2014). This may be the actual reason for any ban as this may be misleading to consumers of fertilizer.

A subsequent review of the NSW Fertilisers Regulation 1997 under the Fertilisers Act 1985 makes no specific mention of melamine or any limit. It does prescribe forms of nitrogen, including nitrogen as urea (Fertilisers Regulation 1997).

The conclusion is that melamine may not deliver significant benefit in terms of a source of available nitrogen however its presence as a component in the focus materials is unlikely to cause harm to human health or the environment.

Formaldehyde

Formaldehyde is a flammable, colourless, highly reactive gas at standard temperature and pressure, and is commonly found in the environment.

Wood waste containing UF resins may be a source of formaldehyde emission by releasing free formaldehyde or degradation of the UF resin in wood waste.

Anaerobic micro-organisms can efficiently reduce formaldehyde.

SoilCo queried the emissions from formaldehyde concerning:

- Safety of workers accepting and processing compost
- Effect on compost process
- Safety of customers. i.e., end-users of the products

Formaldehyde is a known carcinogen, and accordingly the Australian Government's National Industrial Chemicals Notification and Assessment Scheme (NICNAS[1]) recommends maximum emission levels for exposure. Thus, there are strict limits on formaldehyde emissions in Australian standards for the production of all composite wood products – including MDF and particleboard.

Safety of workers is therefore unlikely to be compromised due to formaldehyde exposure from accepting joinery sourced focus materials and processing composts with these materials as an ingredient.

It should be noted that softwood and hardwood wood dust is also a known carcinogen and there are maximum emission levels for exposure. This is why manufacturers such as joineries all have extensive dust collection equipment.

The effect of the Focus Materials on the composting process, in particular the soil biota, is unknown and is why further research is recommended.

Conclusion

The General RRO and RRE specifically exclude engineered wood products such as the Focus Materials. However, there is enough published research available and analysis results to support a conclusion that EWPs with urea formaldehyde:

- will not cause harm to human health or the environment
- would be beneficial or fit-for-purpose in a composted product.

In the case of EWP resins melamine, melamine formaldehyde, and urea formaldehyde, the research suggests that it will not cause harm to human health or the environment. The resins could be beneficial in a composted product. However, there are some data gaps.

We recommended that research is undertaken specifically on resins melamine, melamine formaldehyde and urea formaldehyde and their degradation in soil applications to assess any possible:

1. harm to human health or the environment

[1] NICNAS is the Australian government's regulatory body for industrial chemicals. NICNAS is designed to help protect workers, the public, and the environment from the harmful effects of industrial chemical. This organisation is in transition to AICIS – the Australian Industrial Chemicals Introduction Scheme.

2. benefits as an additive in a composted product.

Industrial heat recovery

Using Focus Material to generate heat means that it is being used as fuel and therefore, in NSW, must comply with the resource recovery framework for wastes. The process is simpler for wastes classified as eligible waste fuels. These are defined in the Eligible Waste Fuel Guidelines (NSW EPA 2016).

Focus Materials almost qualify as an eligible waste fuel under the definition of uncontaminated wood waste and for the simplified approval process. Uncontaminated wood waste is defined as:

> *"Uncontaminated wood waste includes pre-consumer manufacturing and processing waste materials such as off-cuts, saw dust, wood shavings, untreated packaging crates, untreated pallets and engineered timbers made with urea formaldehyde or phenol formaldehyde resins only."*

As discussed previously, the Focus Materials also comprise melamine formaldehyde and melamine urea formaldehyde. Why MF and MUF were not included when phenol formaldehyde is included is puzzling. Phenol formaldehyde is the resin used for most structural plywood products and requires a much higher temperature to breakdown.

Despite this omission, as these Guidelines are not included in Regulation, the NSW EPA has some flexibility in this matter and is likely to view an application that addresses all other parameters in the Guidelines favourably. This includes chemical characterisation, quality assurance, and quality control processes to ensure Group 6 emissions limits will be continuously met.

The approval process for waste-derived fuels that are not eligible waste fuels is set out in the Energy from Waste Policy Statement. This is a much more demanding approval process, and anything other than a purpose-built waste incineration facility or a cement kiln would not meet the technical requirements to utilise the focus materials as fuels.

Either way, energy recovery facilities must comply with the air emissions limits in their site Environmental Protection Licence (EPL) or those in Group 6 air emissions standards defined in the Protection of the Environment Operations (Clean Air) Regulation.

5. Circular economy solutions assessment

Considering the previous research, the following Table 7 summarises each solution, what materials are substituted, any specific requirements/restrictions, a circularity potential, and an estimate of the timeline for implementation once a decision is chosen to proceed.

CE Strategy	CE Solution	Substitute for / reduce use of	Specific notes/requirements	Circularity potential	Timeline/availability in ISJO[2]	Potential demand (tpa)	Suitability of ISJO material (if facility approved)			
							Joinery generated			EoL
							PB offcuts	MDF offcuts	Saw dust	All
Reuse	Internal reuse of offcuts	• New particleboard • New MDF	• Limited options due to size and shape of offcuts • Limited joinery storage capacity	Very high	Now	Unknown	✓	✓	×	×
	External reuse of offcuts	• New particleboard • New MDF	• Limited options due to size and shape of offcuts • Cooperation of council reuse facilities needed • Transport distance and impacts	Very high	Now	Unknown	✓	✓	×	×
	Reuse of second-hand cabinets	• New particleboard • New MDF	• Limited options due to size and shape of cabinets • Opportunities in standardisation of dimensions to enhance reuse potential	Very high	Now	Unknown	×	×	×	✓
Recycling into new wood products	Particleboard panels & flooring	• Virgin wood • Virgin wood processing residue	• Production in NSW (Oberon) • Existing RRO/RRE • No sawdust or MDF	High	Now	125,000[3]	✓	×	×	×
	Pallet blocks	• Imported pallet blocks • Virgin wood	• No production in Australia • No sawdust or MDF	High	2-3 years	nil	×	×	×	×
Recycling into new	Wood-plastic composites	• Virgin wood processing residue	• No production in NSW	Medium / low	N/A	nil	×	×	×	×

[2] Time from decision to proceed.

[3] Includes joinery waste focus material and other wood wastes.

CE Strategy	CE Solution	Substitute for / reduce use of	Specific notes/requirements	Circularity potential	Timeline/availability in ISJO[2]	Potential demand (tpa)	Suitability of ISJO material (if facility approved)			
							Joinery generated			EoL
							PB offcuts	MDF offcuts	Saw dust	All
non-wood products	Cement-based products	• Virgin wood	• No further capacity for recovered wood	Medium / low	N/A	nil	×	×	×	×
Recycling into land applied products	Compost input	• Pine bark • Hardwood processing residue	• Research needed. • No sawdust (OH&S) • RRO/RRE required (with specific producer)	Very high (provided biomass source is regenerative)	2-3 years	5,000	✓	✓	✓	×
	Animal bedding component (<5% raw board)	• Urban wood residue • Rice hulls • Virgin wood processing residue	• Raw particleboard offcuts only • No melamine, sawdust or MDF	Very high (provided biomass source is regenerative)	Now (with reDirect) 2-3 years with another processor	20,000	✓	✓	×	×
Industrial heat recovery - onsite	Joinery in ISJO region (with spray booths)	• Natural gas	• Council permission and RRO/RRE required (with specific user)	Medium / low	1-2 years	1,000	✓	✓	✓	×
	Joinery in ISJO region (w/o spray booths)	• N/A	• Council permission and RRO/RRE required (with specific user)	Very low	1-2 years	nil	✓	✓	✓	×
Industrial heat recovery - offsite	Cement production - Boral Berrima	• Thermal coal	• Existing EPL conditions • Must go via Veolia, Sydney	Medium / low	Now	60,000	✓	✓	✓	×
	Power generation - Sunshine Power	• Thermal coal	• Existing RRO/RRE • Distance ~400km • At capacity with local suppliers	Medium / low	Now	nil	×	×	×	×
	Heat recovery – Borg, Oberon	• Bark	• Existing EPL conditions • Could take additional MDF offcuts (not currently interested) • Reverse logistics also needed	Medium / low	Now	20,000	×	✓	×	×
	Starch/food manufacturer – e.g., Shoalhaven Starches, Nowra	• Thermal coal • Natural gas	• Requires RRO/RRE • Expensive refit required (unlikely to invest)	Medium / low	2-3 years	nil	×	×	×	×
	Power generation - Hunter Energy, Redbank	• Thermal coal • Natural gas • Renewable energy	• Requires RRO/RRE • Distance ~400km • Could take MDF, distance prohibitive	Medium / low	2-3 years	nil	×	✓	×	×

CE Strategy	CE Solution	Substitute for / reduce use of	Specific notes/requirements	Circularity potential	Timeline/availability in ISJO[2]	Potential demand (tpa)	Suitability of ISJO material (if facility approved)			
							Joinery generated			EoL
							PB offcuts	MDF offcuts	Saw dust	All
	Steel production - BlueScope Steel, Port Kembla	• Coking coal • Charcoal from virgin wood	• Requires RRO/RRE • Pyrolysis infrastructure required.	Medium / low	5-10 years	nil	✓	✓	×	×
	Greenhouse, poultry farms, timber drying	• Natural gas • LPG	• Requires RRO/RRE • No sites identified	Medium / low	N/A	nil	×	×	×	×
	Power generation - WtE facility (e.g. Mt Piper)	• Thermal coal • Natural gas • Renewable energy	• Suitable for end-of-life focus materials • No facility with planning approval in NSW	Medium / low	5-10 years	nil	✓	✓	✓	✓

Table 7: Circular economy solutions for the focus materials

6. Aggregation / reverse logistics

Aggregation and reverse logistics arrangements can be the difference between a good (reduced environmental impact) decision and a poor (higher impact) solution. Life cycle assessment studies regularly show that solutions that require significant transport to distant markets in dedicated diesel trucks can negate any environmental benefit from the reuse and/or recycling of resources.

Long-distance transport of low-quality biomass is also not generally feasible for low-value products such as energy or electricity generation unless transport is free or very low cost and only uses renewable energy. Electrification of transport options is a key enabler of genuinely circular solutions – otherwise, fossil fuel-based transport could negate the circular economy benefits being pursued.

Transport over longer distances is more feasible and lower impact if recovered materials:

- replace a higher value or unavailable input
- are converted into a high-value product
- are densified
- are aggregated into large quantities ready for transport
- utilise space in previously empty trucks (are backloaded).

For example, Borg owned reDirect Recycling is organising reverse logistics in their operations to take back multiple products (purchased from their polytec business) for recycling and energy recovery at Oberon. See Figure 15. The offcuts incorporated into new particleboard panels have a wholesale value of around $500 per tonne. Offcuts of MDF utilised for energy recovery replace bark which is in very high demand in the horticulture and landscaping markets as an input to organic products.

Figure 12: reDirect Recycling is rolling out a front lift particleboard offcut collection service from late 2020.

7. Recommendations and next steps

The project has estimated that around 5,031 tonnes of MDF offcuts, particleboard offcuts, and sawdust are generated in the ISJO region each year by approximately 100 joineries and kitchen manufacturers. This estimate excludes waste generated by the cutting of sawn timber, plywood, and other products.

Looking at the potential through a Circular Economy lens, we have developed some recommendations and next steps for ISJO.

Our recommendations focus on ISJO facilitating:

- greater reuse of offcuts
- research into the potential benefits of melamine formaldehyde and melamine urea formaldehyde in land-applied products
- recycling of panel offcuts into new particleboard via Borg/reDirect Recycling
- uptake of approved heat energy generation onsite at joineries where heat is needed onsite
- uptake of heat energy offsite at larger facilities outside the region.

Recommendation 1: Facilitate greater reuse

We identified opportunities for joineries and kitchen manufacturers to trade or swap offcuts. Making offcuts available to the public consumers undercuts markets for finished product however, and would not be feasible. Business to business (B2B) trade avoids this issue.

Various business recycling trading platforms (such as Planet Ark's Business Recycling website – supported by the NSW Government) and NSW EPA Bin Trim programmes (NSW EPA 2020g) have attempted this.

ISJO could facilitate a local business-to-business reuse programme in Unanderra and nearby Shellharbour where there is a concentration of similar joinery and kitchen manufacturing businesses.

Alternatively, suitable size MDF and particleboard offcuts for low-cost sale could be supplied at local reuse centres such as Dunmore Resources & Recycling Centre and Shoalhaven Recycling & Waste Depot at West Nowra.

Next steps for ISJO

ISJO work with member councils and their reuse centres to facilitate an offcut reuse programme.

Recommendation 2: Research into safe use and potential benefits of focus materials in land-applied products.

We recommend the ISJO evaluate the Focus Materials made with the most common resins for their biodegradability and safety in recycled products that are applied to land (including compost). The research would aim to find out a set rate of engineered wood products allowed in compost for land application, to be approved under a NSW EPA resource recovery order and resource recovery exemption.

Desktop research funded by the Australian timber industry's research and development body Forest and Wood Products Australia (FWPA) has been conducted into the safe levels of preservatives in various reuse applications (Hann *et al.* 2014). This research has been used by the timber industry to inform state environmental protection agencies' policies and regulations.

We recommend that ISJO facilitate research in the safe levels of melamine urea formaldehyde and melamine formaldehyde in land-applied applications.

Given the NSW EPA's stance on engineered wood products in the RRO and RRE for compost and mulch, we also recommend compost trials containing the focus materials to understand the effects including benefits on growing plants and soil biota.

Discussions have been had with University of Sydney about such a project. It is estimated that research and a trial would take two years after funding is attained and cost an estimated $200,000. (Professor Balwant Singh *pers. comm.* 17 November 2020).

The Australian timber industry's research and development body Forest and Wood Products Australia (FWPA) has funded research on end-of-life options for wood products (e.g., Hann *et al.* 2010, Taylor *et al.* 2005). MDF was identified in a list of main products of concern as needing to be addressed from a circular economy perspective in a recent report produced for the FWPA (FWPA 2020). FWPA could be very interested in funding some researchers to focus on this issue and recommend that ISJO contact FWPA to facilitate local participation in research.

<u>Next steps for ISJO</u>

ISJO work with University of Sydney to obtain funding to research composting of particleboard and MDF generated by joineries. NSW EPA, Forest and Wood Products Australia and/or Australian Research Council should be targeted for funding.

Recommendation 3: Facilitate recycling of particleboard offcuts into new particleboard

Recycling is currently the greatest opportunity for particleboard offcuts. reDirect Recycling promotes a low-cost collection service and has facilities at Ingleburn and St Marys for aggregation. They transport particleboard over the mountains to the Borg Manufacturing facility at Oberon.

Given the distances, we recommend an aggregation point in the ISJO region. ISJO could facilitate an aggregation point at polytec's distribution centre in South Nowra whereby polytec vehicles delivering product to joineries back load offcuts to the distribution centre.

thinkstep-anz could assist with a carbon footprint cost/benefit analysis to make sure negative impacts are minimised, as reverse logistics is a known impact point for Circular Economy (CE) systems.

Next steps for ISJO

ISJO work with reDirect Recycling to establish takeback service and an aggregation point in the region for particleboard offcuts.

Recommendation 4: Facilitate uptake of heat energy generation onsite

This option has been employed by two joineries in the Canberra/Queanbeyan region and is being actively pursued by joineries in the ISJO region. Businesses located in the ISJO region do not have heating needs as great as businesses located in the Canberra/Queanbeyan region. However, by using sawdust to generate heat energy onsite, the savings for waste disposal costs would be significant.

Wood Tech estimates that a business spending over $8,000 per month on waste disposal costs would find this feasible. We estimate that of the six major joineries in the ISJO region, at least four would find a wood waste heater feasible.

For this solution to achieve circularity benefits, the heat generated must be productively used all year round.

We recommend facilitating monitoring of the air emissions for current system installations. If they do meet NSW standards, then it is likely that the larger joineries in the ISJO region will take the opportunity to install these appliances.

Next steps for ISJO

ISJO monitor air emissions compliance of current air heating system installations. If air emissions do not meet regulations than joineries in the region should be notified of this.

If air emissions limits are met – ISJO could facilitate installation in joineries where the heat generated is utilised all year round.

Recommendation 5: Facilitate uptake of heat energy offsite

For some materials, especially Focus Materials such as end-of-life kitchen cabinets and joinery, options are very limited. The only best use available for the bulk of material being generated is energy recovery.

We have identified several facilities than can, or could once operational, take these Focus Materials generated in the region and utilise them to generate heat for industrial processes or for power generation.

Three facilities in NSW are currently operating with appropriate planning and NSW EPA permission (via their environmental protection licence or EPL) to accept EWPs such as the focus materials as fuel. These facilities are a considerable distance from the ISJO region and have sufficient supply close to where they are located.

Two facilities are in development. One facility - Hunter Energy, Redbank is at prefeasibility stage. Another facility - Mt. Piper Energy Recovery Project is at an advanced approval stage.

These facilities are all quite a distance from the ISJO region. The need for significant transport from the region can impact viability on both economic and environmental models. We note that electrification of transport is happening rapidly in many parts of the world. Cheaper transportation costs brought about by electrification and the availability of renewable energy will make transport to distant facilities more feasible.

Next steps for ISJO

ISJO monitor status of current and soon-to-be-approved energy recovery facilities that could take the focus materials.

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Appendices

Appendix 1: Definitions and Abbreviations

ABS (acrylonitrile butadiene styrene) - a thermoplastic commonly used to make edge tape for application to panels in joineries.

Biochar - charcoal produced by pyrolysis of biomass in the absence of oxygen and used as a soil ameliorant for both carbon sequestration and soil health benefits.

CE - Circular Economy

Charcoal - a lightweight black carbon material produced by pyrolysis of biomass in the absence of oxygen.

EoL (end-of-life). A product at the end of its original intended lifecycle (from the product vendor's point of view).

EPA (Environment Protection Authority of NSW)

EPL (Environment Protection Licence) - issued by the EPA to the owners or operators for an industrial premise to undertake various activities under the Protection of the Environment Operations Act 1997 (POEO Act).

EWP (engineered wood products). as defined by the NSW EPA in resource recovery orders and exemptions for land-applied waste means engineered, painted, treated or composite wood products such as particleboard, oriented strand board, plywood, laminated veneer lumber, glulam or fibreboard that are manufactured with glues, resins, water repellents, fire retardants, fungal inhibitors and/or other chemicals.

Focus materials - a combination of mainly medium density fibreboard (MDF), particleboard, and timber generated by joineries and kitchen manufacturers.

FSC - Forest Stewardship Council

MDF (medium-density fibreboard) - a reconstituted wood panel product manufactured from wood fibres and resin.

MF (melamine formaldehyde) - a thermosetting resin commonly used as an adhesive in manufacture of wood-based panels including MDF and particleboard.

MUF (melamine urea formaldehyde) – a thermosetting resin commonly used as an adhesive in manufacture of wood-based panels including MDF and particleboard.

Particleboard - a reconstituted wood panel product manufactured from wood particles or flakes.

PB (particleboard)

PEFC – Programme for Endorsement of Forest Certification (includes the Australian Responsible Wood certification program).

Post-consumer waste - material waste generated by households or by commercial, industrial, and institutional facilities in their role as end-users of the product which can no longer no used for its intended purpose. This includes returns of material from the distribution chain. Definition from AS 14021:2018.

PP (polypropylene) - a thermoplastic used to make edge tape for application to panels in joineries. Not as common as ABS.

Pre-consumer waste - material diverted from the waste stream during a manufacturing process. Excluded is reutilization of materials such as rework, regrind or scrap generated in a process and capable of being reclaimed within the same process that generated it. Definition from AS 14021:2018.

PVC (polyvinyl chloride) - a thermoplastic that used to be commonly used to make edge tape for application to panels in joineries. Very uncommon now.

RRE (Resource Recovery Exemption) - a legal document issued by the NSW EPA for consumers for an exemption from the NSW waste levy and some specific environmental regulations for using waste-derived materials in land application, as a fuel or use in a thermal process.

RRO (Resource Recovery Order) - a legal document issued by the NSW EPA for producers of waste-derived materials in land application, as a fuel or use in a thermal process. It sets out the parameters of such production and exempts producers from the NSW waste levy and some specific environmental regulations provided it is produced in compliance with the order.

UF (Urea formaldehyde) - a thermosetting resin commonly used as an adhesive in manufacture of wood-based panels including MDF and particleboard.

Appendix 2: Specifications and standards

Several standards and specifications are relevant to development of markets for the Focus Materials and quality assurance purposes and are included below.

Particleboard

While use of the Focus Materials in new particleboard in NSW will be driven by the regulatory regime in place in NSW (See Section 4) due to the high prevalence of recycled wood being used in the panel industry in Europe the European panel industry has developed a standard for recycled wood inputs (European Panel Federation 2018). See Table 8. The limit values for a range of elements/compounds are based on another European Standard for materials used as toys.

Elements / Compounds	***Limit values (mg/kg recycled wood)***
Arsenic (As)	25
Cadmium (Cd)	50
Chromium (Cr)	25
Copper (Cu)	40
Lead (Pb)	90
Mercury (Hg)	25
Fluorine (F)	100
Chlorine (Cl)	1000
Pentachlorophenol (PCP)	5
Creosote (Benzo(a)pyrene)	0,5

Table 8 Limit values in particleboard for contaminants that may be present in recycled wood (EPF 2018)

Soil applications

The relevant standard in these group of products is the Australian Standard *AS 4454:2012 Composts, soil conditioners and mulches.*

Energy recovery

The specifications for waste derived solid fuels is very much dependent on regulation. Input specifications depend on the type of fuel, the plant including type of boiler and how fuel is burnt and associated pollution control equipment.

At the international level, a series of standards has been developed for Solid Recovered Fuels (SRFs). These are fuels produced from any non-hazardous waste that can be specified and classified for a specific recovery or energy conversion purpose. Other purposes may, for example, be chemical recycling and mineral input into cement manufacture (ISO 2020).

Appendix 3: reDirect Recycling particleboard recycling


CREATING A
COMPLETE &
SUSTAINABLE
LOOP
DO NOT FILL ABOVE RIM
reDirect
1300 001 306
PARTICLEBOARD ONLY
A Borg company
Particleboard Waste
PROCESS FLOW
1 Bins are supplied to your site and serviced once full via reDirect trucks
2 Waste is taken to a reDirect Material Recovery Facility for processing
3 Waste is sorted and processed efficiently using machinery
4 Waste material is extracted and re-purposed
5 The re-purposed material is manufactured into new and saleable products
Acceptable Inputs
Raw particleboard offcuts
Melamine coated particleboard offcuts (no edge tape)
Unacceptable Inputs
MDF
Hardboard/masonite, painted or unpainted
Edgetape
Wood mixed with rubbish, paper, plastics, etc.
Window frames (may contain lead paint or silicone inserts)
Doors

Appendix 4: Chemical characterisation analysis results summary

		Virgin sawn softwood pine		Focus materials (joinery sawdust) Results by Joinery and Sample No.					
Substance	Unit	mean or range (unless indicated)	source	#1	#2	#3	#4	#5	#6
Antimony	mg/kg	<5	a	<5	<5	<5	<5	<5	
Arsenic	mg/kg	<5	a	<5	<5	<5	<5	<5	
Beryllium	mg/kg	<1	a	<1	<1	<1	<1	<1	
Boron	mg/kg	<3	a	<3	<3	<3	<3	<3	
Cadmium	mg/kg	<1	a	<1	<1	<1	<1	<1	
Chromium	mg/kg	<2	a	<2	<2	<2	<2	<2	
Cobalt	mg/kg	<1	a	<1	<1	<1	<1	<1	
Copper	mg/kg	<5	a	<5	<5	<5	<5	<5	
Lead	mg/kg	<5	a	<5	<5	<5	<5	<5	
Manganese	mg/kg	15-188	c	48	15	11	14	48	
Mercury	mg/kg	<0.1	a	<0.1	<0.1	<0.1	<0.1	<0.1	
Molybdenum	mg/kg	<1	a	<1	<1	<1	<1	<1	
Nickel	mg/kg	<2	a	<2	<2	<2	<2	<2	
Selenium	mg/kg	<5	a	<5	<5	<5	<5	<5	
Tin	mg/kg	<5	a	<5	<5	<5	<5	<5	
Vanadium	mg/kg	<5	a	<5	<5	<5	<5	<5	
Zinc	mg/kg	1-69	c	11.2	7.0	4.8	40.3	6.7	
Total Sulphur	mg/kg	0.01	b	0.05	0.02	0.03	0.02	0.05	
Air Dried Moisture	% as received	11.9	b	4.3	4.1	4.3	3.4	4.2	
Ash	% as received	0.2	b	0.9	1.0	1.0	0.6	0.8	
Calorific Value	% as received	16.74	b	19.48	19.21	19.43	19.28	19.04	
Moisture content	% as received	12	e	5.4	5.9	7.2	6.8	4.8	
pH (1:5) in water	pH units	4.0-4.8	d	5.2	5.4	5.1	4.9	5.4	
Electrical Conductivity (1:5)	dS/m	NA	-	0.49	0.35	0.38	0.58	0.62	
Phosphorus (P) - Total	% dry wt	7-50	b	0.009	0.009	0.008	0.005	0.009	
Nitrogen (N) - Total	% dry wt	0.8 (stem) 3.1 (bark)	e	4.24	5.2	3.48	1.27	4.71	
Wettability	min	NA	-	7	7	7	1.02	7	
Glass, metal, rigid plastics >2mm	% Retained	<0.01	a	<0.01	<0.01	<0.01	<0.01	<0.01	0.244
Light plastic >5mm	% Retained	<0.01	a	<0.01	<0.01	<0.01	<0.01	<0.01	0.07
Stones & lumps of clay ≥5mm	% Retained	<0.01	a	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Sources for virgin softwood pine:	a	industry sources
	b	CSIRO (2020): Database of chemical properties of Australian biomass and waste. v15. CSIRO. Data Collection. 10.25919/18ft-bc25. Chemistry for Pine sawmill waste (softwood)from Oberon, NSW. Accessed https://csiroenergy.shinyapps.io/biomass/
	c	Lambert, M. (1981) Inorganic Constituents in Wood and Bark of New South Wales Forest Tree Species. Forestry Commission of NSW, Research Note No. 45. Table 9 - Result for sapwood and heartwood.
	d	Bootle, K. (2005) Wood in Australia. 2nd Edition. McGraw Hill Australia.
	e	Ximenes, F., Ramos, J., Bi, H., Cameron, N., Singh, B. and Blasii, M. (2012) Determining Biomass in Residues Following Harvest in Pinus radiata Forests in New South Wales. RIRDC Publication No. 11/177. Project No. PRJ-005725. Table 18.

One of the joineries was utilising a high proportion of sawn timber – mainly spotted gum – so the results for this sample (#4) are different for several characteristics.

Appendix 5: Test result statistics and comparison with compost & fuel limits

		Results by Joinery and Sample No. (100% LOQ value substituted if value <LOQ)						Statistics				European Panel Federation	AS4454:2012 requirement for Raw Mulch unless noted		Wood waste fuel (input limits)	
Characteristic	**Unit**	**#1**	**#2**	**#3**	**#4**	**#5**	**#6**	**Average**	**Min**	**Max**	**SD**	**Limits (mg/kg recycled wood**	**Limits**	**notes on limits**	**Limits (typical)**	**notes on limits**
Antimony	mg/kg	5	5	5	5	5		**5**	**5**	**5**	**0**	No requirement	No requirement		Facility dependent aggregated with other Type 1 & 2 substances	Type 1 substance
Arsenic	mg/kg	5	5	5	5	5		**5**	**5**	**5**	**0**	25	20		Facility dependent aggregated with other Type 1 & 2 substances	Type 1 substance
Beryllium	mg/kg	1	1	1	1	1		**1**	**1**	**1**	**0**	No requirement	No requirement		Facility dependent aggregated with other Type 1 & 2 substances	Type 2 substance
Boron	mg/kg	3	3	3	3	3		**3**	**3**	**3**	**0.0**	No requirement	100		No requirement	
Cadmium	mg/kg	1	1	1	1	1		**1**	**1**	**1**	**0**	50	1		Facility dependent aggregated with other Type 1 & 2 substances and individial limit	Type 1 substance
Chromium	mg/kg	2	2	2	2	2		**2**	**2**	**2**	**0**	25	100		Facility dependent aggregated with other Type 1 & 2 substances	Type 2 substance
Cobalt	mg/kg	1	1	1	1	1		**1**	**1**	**1**	**0**	No requirement	No requirement		Facility dependent aggregated with other Type 1 & 2 substances	Type 2 substance
Copper	mg/kg	5	5	5	5	5		**5**	**5**	**5**	**0**	40	150		Facility dependent	
Lead	mg/kg	5	5	5	5	5		**5**	**5**	**5**	**0**	90	15		Facility dependent aggregated with other Type 1 & 2 substances	Type 1 substance
Manganese	mg/kg	48	15	11	14	48		**27.2**	**11**	**48**	**19**	No requirement	No requirement		Facility dependent aggregated with other Type 1 & 2 substances	Type 2 substance
Mercury	mg/kg	0.1	0.1	0.1	0.1	0.1		**0.1**	**0.1**	**0.1**	**0**	25	1		Facility dependent aggregated with other Type 1 & 2 substances and individial limit	Type 1 substance
Molybdenum	mg/kg	1	1	1	1	1		**1**	**1**	**1**	**0**	No requirement	No requirement		No requirement	
Nickel	mg/kg	2	2	2	2	2		**2**	**2**	**2**	**0**	No requirement	60		Facility dependent aggregated with other Type 1 & 2 substances	Type 2 substance
Selenium	mg/kg	5	5	5	5	5		**5**	**5**	**5**	**0**	No requirement	No requirement		Facility dependent aggregated with other Type 1 & 2 substances	Type 2 substance
Tin	mg/kg	5	5	5	5	5		**5**	**5**	**5**	**0**	No requirement	No requirement		Facility dependent aggregated with other Type 1 & 2 substances	Type 2 substance
Vanadium	mg/kg	5	5	5	5	5		**5**	**5**	**5**	**0**	No requirement	No requirement		Facility dependent aggregated with other Type 1 & 2 substances	Type 2 substance
Zinc	mg/kg	11.2	7.0	4.8	40.3	6.7		**14.0**	**4.8**	**40.3**	**14.9**	No requirement	300		No requirement	

		Results by Joinery and Sample No. (100% LOQ value substituted if value <LOQ)						Statistics				European Panel Federation	AS4454:2012 requirement for Raw Mulch unless noted		Wood waste fuel (input limits)	
Characteristic	**Unit**	**#1**	**#2**	**#3**	**#4**	**#5**	**#6**	**Average**	**Min**	**Max**	**SD**	**Limits (mg/kg recycled wood**	**Limits**	**notes on limits**	**Limits (typical)**	**notes on limits**
Total Sulphur	mg/kg	0.05	0.02	0.03	0.02	0.05		**0.03**	**0.02**	**0.05**	**0.02**	No requirement	No requirement		10,000 (1%)	
Air Dried Moisture	%	4.3	4.1	4.3	3.4	4.2		**4.1**	**3.4**	**4.3**	**0.38**	No requirement	No requirement		No requirement	
Ash	%	0.9	1.0	1.0	0.6	0.8		**0.9**	**0.6**	**1.0**	**0.17**	No requirement	No requirement		< 5	
Calorific Value	MJ/kg	19.48	19.21	19.43	19.28	19.04		**19.29**	**19.04**	**19.48**	**0.18**	No requirement	No requirement		≥15	
Moisture content	%	5.4	5.9	7.2	6.8	4.8		**6.0**	**4.8**	**7.2**	**1.0**	No requirement	≥ 25	Requirement for pasteurized and composted product - no minimum for raw mulch.	< 15	
pH (1:5) in water	pH units	5.2	5.4	5.1	4.9	5.4		**5.2**	**4.9**	**5.4**	**0.2**	No requirement	≥ 5	pH limit is for finished product (not inputs).	No requirement	
Electrical Conductivity (1:5)	dS/m	0.49	0.35	0.38	0.58	0.62		**0.5**	**0.4**	**0.6**	**0.1**	No requirement	≤ 10		No requirement	
Phosphorus (P) - Total	% dry wt	0.009	0.009	0.008	0.005	0.009		**0.008**	**0.005**	**0.009**	**0.0**	No requirement	≤ 0.1	Requirement for products that claim to be for phosphorus-sensitive plants. No requirement otherwise.	No requirement	
Nitrogen (N) - Total	% dry wt	4.24	5.2	3.48	1.27	4.71		**3.78**	**1.27**	**5.2**	**1.5**	No requirement	≥ 0.8	Requirement if a contribution to plant nutrition is claimed.	Facility dependent	
Wettability	min	7.00	7.00	7.00	1.02	7.00		**5.80**	**1.02**	**7.00**	**2.67**	No requirement	<5	Requirement for mature composted product - no maximum for raw mulch or pasteurized product.	No requirement	
Glass, metal, rigid plastics >2mm	% Retained	0.01	0.01	0.01	0.01	0.01	0.24	**0.05**	**0.06**	**0.06**	**0.07**	No requirement	≤ 0.5		Glass, metal included in ash limit. Rigid plastic limit facility dependent.	
Light plastic >5mm	% Retained	0.01	0.01	0.01	0.01	0.01	0.07	**0.02**	**0.02**	**0.02**	**0.03**	No requirement	≤ 0.05		Facility dependent	
Stones & lumps of clay ≥5mm	% Retained	0.01	0.01	0.01	0.01	0.01	0.01	**0.01**	**0.01**	**0.01**	**0.01**	No requirement	≤ 5		Included in ash limit	