REPORT: ASSESSMENT OF THE VOLUMES OF WOOD BIOMASS RESIDUES AND THEIR POTENTIAL USES AND MARKETS

August 2022

Bioenergy & Carbon

This report was commissioned by the South & Central Queensland Regional Forestry Hub with funding from the Australian Government, Department of Agriculture, Fisheries and Forestry

South and Central Queensland Regional Forestry Hub - Biomass availability inventory and potential markets project report

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1 Executive summary

The study investigated the quantities, locations and current or potential uses for woody waste from forest and plantation harvesting, primary and secondary processing, and commercial, industrial, construction and demolition activities in southern and central Queensland.

The study highlighted a number of key issues affecting the likelihood of finding uses/customers for woody waste:

- Delivered costs. As most woody waste is of low value, low delivered costs is often critical to its competitiveness with alternative wood (or other substitute) sources.
- Landfill costs. High landfill costs may make it profitable to reuse/recycle wood waste obtained from waste producers for a lower charge than their existing landfill costs.
- Contamination. Contamination levels in woody waste are a key determinant of its potential uses and value. Contamination may increase costs through the requirement for additional processing (see next point) or, in the case of treatments or coatings, may restrict its potential uses.
- Processing requirements. Every additional processing step adds to the cost of reusing wood waste. Examples of processing common to many waste wood sources include removal of contaminants or less desirable constituents of the material prior to its use and comminution to the required particle size.

Woody waste resources available in the study area form a hierarchy in terms of their usability and their attractiveness to potential users. At the bottom of the hierarchy are native hardwood forest logging residues, municipal and demolition waste and CCA treated timber. At the top of the hierarchy is sawmill waste from softwood sawmills. In between are woody waste from commercial and industrial activities, (excluding softwood sawmill waste), construction waste and softwood plantation logging residue. It should be noted that before waste wood can be used as a resource, the Queensland Department of Environment and Science must first develop an End Of Waste (EOW) code for that specific waste material. The EOW code describes (amongst other things) the waste to which the EOW code applies, the conditions of use and penalties for supplying a resource without complying with the conditions of use. An EOW approval may be granted prior to the issue of an EOW code to allow a proposed use of waste material to be trialled. There are currently two relevant EOW codes allowing:

- The use of ACQ shavings as a component of no more than 5% in the manufacture of compost or mulch
- The use of chemically treated solid timber to manufacture engineered wood products or dimensioned timber products

Native hardwood forests and plantations in the study area produce substantial quantities of logging residue (~165,000t/yr (oven dry weight)), however, it is unlikely that this resource could support a major industry due mainly to its low spatial density. Other unfavourable factors include the planned cessation of logging in State native hardwood forests in south-east Queensland in the next four years, the lack of coordination of harvesting decisions by private native hardwood forest owners, impacting planning by potential users, and the relatively low quality of the residue as biofuel. Small-scale and/or opportunistic uses of native hardwood logging residue may be possible, for example, as firewood.

Approximately 500,000t per year of woody waste from municipal and demolition waste streams is sent to landfill in Queensland. Woody waste from these sources is amongst the least desirable for recycling or re-use (excluding high-value materials removed prior to demolition such as floor boards and large dimension timber pieces) due to its high potential for contamination from a wide range of sources, in particular treated wood and paint or other coatings with high levels of heavy metals, and the potential for mixtures of wood types with varying properties. Removal of contaminants would be likely to involve manual processing and screening increasing the cost of reclaiming these materials. The contamination risk and range of timber properties in these waste streams means that the material is only likely to be suitable for use as boiler fuel at a facility where emissions are controlled.

The quantity of CCA treated timber disposed of annually in the study area is unknown. CCA treated timber can be used as a component of engineered wood products (EWPs) under an existing Queensland EOW code. However, those using or disposing of these EWPs would need to be notified of the CCA component. CCA treated timber could potentially be used as boiler fuel or in pyrolysis or as a minor component of compost or mulch if EOW codes were obtained. Hazardous components of CCA treated timber can be reduced through biological and chemical means but the cost is likely to be prohibitive.

High-quality wood waste can be obtained from commercial and industrial activities and large construction projects where waste quantities and site supervision levels are high and waste types can be separated at source. Smaller construction sites have little incentive to recycle waste and often insufficient room for multiple skips. Estimated total quantities of woody waste from these streams available in Queensland (excluding sawmill waste) are ~200,000t. A considerable, but unknown, proportion of this waste is from Brisbane and surrounds, which were not part of the study area. Potential uses include boiler fuel, particle board manufacture and as a component of compost or mulch, if EOW codes were obtained. Higher landfill costs would incentivise producers of woody waste in these sectors and waste collection firms to divert woody waste from landfill as has been found in NSW. The impact of increasing use of H2F envelope treated timber in construction on the potential uses of construction waste requires further research.

Estimated logging residue available at roadside from softwood plantations in south and central Queensland consists of approximately 64,500 dry tonnes per year from southern pine plantations and approximately 59,800 dry tonnes per year from Araucaria plantations. Logging residue (unutilisable stem components) from southern pine plantations is currently being used for a range of purposes. There is considerable scope to increase the use of this resource and to use the Araucaria logging residue.

Considerable quantities of softwood sawmill waste (~850,000m^3 per year combined southern pine and Araucaria) are produced in the study area, predominantly from four sawmills. This concentrated, consistent, high-quality resource is in demand for a range of uses, including particle board and MDF manufacture, export wood chips, export wood pellets, animal bedding, boiler fuel and compost/mulch. With increasing fossil fuel prices and global moves to reduce greenhouse gas emissions, there is scope to increase export of wood pellets to Asia and Europe. In contrast, waste from native hardwood sawmills is less desirable as it is produced in relatively small quantities from small sawmills spread across the study area (~163,000m^3) and from a range of species. Uses for this waste are more limited than softwood sawmill waste and consist predominantly of landscaping and fuel.

Production of liquid or gaseous biofuels from sawmill waste or logging residue is currently more expensive than production from other sources or fossil fuels. The need to find alternatives to fossil fuels and 1st generation liquid biofuels (produced using edible feedstocks), is driving considerable interest and research in this area aimed at lowering production costs. Production of other bio-based substances from sawmill waste to replace fossil fuel-derived chemicals has the potential to be a major export opportunity for Australia. However, as with biofuels, this is an area of active research.

In recent years, Queensland government recycling and waste reports have provided no information on the quantity of unused individual waste components, reporting only the aggregated high-level values. Reporting on individual waste components does not provide information on unused quantities. There is a pressing need for an up-to-date audit of the unused components of Queensland landfill waste streams to determine the quantities and locations of unused timber and other waste materials that could potentially be recovered.

2 Background

Each year Australia produces millions of tonnes of potentially usable residues from forest harvesting, primary and secondary timber processing and construction and demolition operations. While currently there is a level of utilisation of this material by industries in Queensland, particularly in some sectors, there is a considerable quantity of residue material that is currently unused. Potential uses for residues include biofuel production (chipped residue, wood pellets/briquettes liquid fuels), wood chips for paper or particle board production, recycled construction materials (beams, posts, floorboards, doors, etc), animal bedding, kitty litter and the production of industrial chemicals and bio-polymers.

Utilisation of waste materials, including forest and timber residues, typically commences with the easiest and cheapest sources ("low hanging fruit") and/or those with the greatest potential returns. Therefore, an important consideration of the current project is the identification of the major barriers and impediments limiting the use of currently unutilised harvesting and timber residues to encourage higher levels of residue use. Of particular concern are chemically treated timber wastes as regulatory authorities have generally recommended disposing of them in landfill regardless of type of treatment.

3 Project scope

The project scope is limited to stakeholders operating within the following Queensland local government areas (LGAs):

- Banana Shire Council
- Bundaberg Regional Council
- Central Highlands Regional Council
- Cherbourg Aboriginal Shire Council
- Fraser Coast Regional Council
- Gladstone Regional Council
- Goondiwindi Regional Council
- Gympie Regional Council

- Livingstone Shire Council
- Lockyer Valley Regional Council
- Maranoa Regional Council
- Moreton Bay Regional Council
- Noosa Shire Council
- North Burnett Regional Council
- Rockhampton Regional Council
- Scenic Rim Regional Council
- Somerset Regional Council
- South Burnett Regional Council
- Southern Downs Regional Council
- Sunshine Coast Regional Council
- Toowoomba Regional Council
- Western Downs Regional Council
- Woorabinda Aboriginal Shire Council

4 Objectives

The objectives of the South & Central Queensland Regional Forestry Hub residue project are as follows.

Within the Local Government Areas covered by the South & Central Queensland Regional Forestry Hub:

- Identify the quantity and location of existing and prospective volumes, types and quality (suitability) of both utilised and unutilised:
    - forest residues
    - wood processing (primary and secondary) residues, and timber from construction, demolition and domestic waste – categorised into untreated or chemically treated waste
- Identify potential commercial uses for the unutilised forest residues and wood waste and, for the top three potential uses, detail impediments and challenges to their use
- Identify opportunities to consolidate forest residues and wood waste to improve their utilisation potential
- Identify current commercial uses of the utilised forest residues and wood waste
- Identify relevant federal and state government policies and support programs for bioenergy and the circular economy, and required standards and guidelines that support residue utilisation

- Consult with local environmental regulators and recyclers in Queensland to clarify their understanding of toxicity of H2F and the other treated timber and barriers to recycling of H2F/the other chemically treated timber waste.
- Develop industry guides and promote / disseminate these guides to suppliers of H2F and other chemically treated timber and engineered timber products to help them evaluate the end-of-life recyclability, or recovery for energy, of the offcuts produced from the use of their products when considering the choice of preservative solutions.

5 Outputs

The main project outputs will be in the form of a draft report and final report addressing each of the objectives in the previous section and industry guides related to end-of-life uses for chemically-treated timber. Additional draft reports may be submitted to the South & Central Queensland Regional Forestry Hub as part of the project.

6 Milestones

The project milestones are shown in Table 1.

Table 1. Project milestone deliverables and due dates

Milestone	Deliverable	Due Date
1	Detailed project plan, including stakeholder identification and consultation methodology	20/5/2022
2	Draft report completed and presented to the Hub Committee at different stages of the project life	10/06/2022
3	A final report submitted to the Hub Committee	30/06/2022

7 Biomass availability inventory and potential markets

7.1 Waste Reduction and Recycling Act 2011

Waste materials in Queensland are regulated under the Waste Reduction and Recycling Act 2011[1] . The Act aims to "reduce the consumption of natural resources and minimise the disposal of waste by encouraging waste avoidance and the recovery, re-use and recycling of waste" (Figure 1) where waste is defined in the Environmental Protection Act 1994 (the EP Act) as:

"anything that is left over, or an unwanted by-product, from an industrial, commercial, domestic or other activity; or surplus to the industrial, commercial, domestic or other activity generating the waste. Furthermore, waste can be a gas, liquid, solid or energy, or a combination of any of them. A thing can be a waste whether or not it is of value."

[1] https://www.legislation.qld.gov.au/view/html/inforce/current/act-2011-031

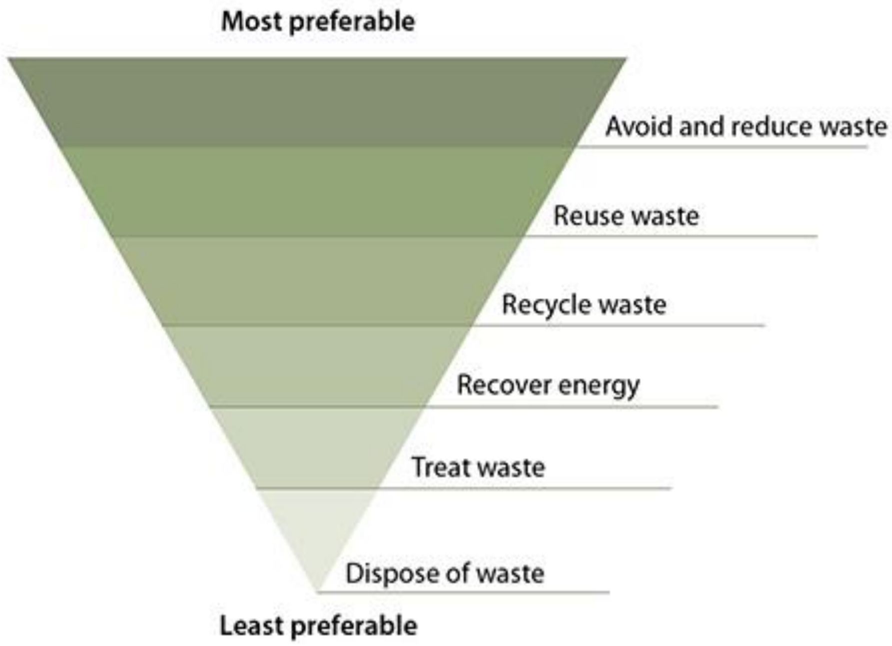

Figure 1. Waste hierarchy

For a waste material to be used as a resource, the Queensland Department of Environment and Science must first develop an End Of Waste (EOW) code for that specific waste material. This allows registered resource producers to sell or give away the resource under the conditions of the EOW code. Amongst other things, an EOW code describes the waste to which the EOW code applies, the conditions of use and penalties for supplying a resource without complying with the conditions of use. Alternatively, an EOW approval may be granted by the Department. An EOW approval is issued to an individual resource producer to allow them to trial the use of a specific waste material as a proof of concept. The process for obtaining an EOW code or approval and becoming a registered resource producer is described in the EOW guideline[2].

7.2 Hardwood forest & plantation residues

7.2.1 Hardwood native forest

Native forest logging residues available annually in the study area (see Section 3) were determined using the methodology of Ngugi et al. (2018). This methodology estimated total logging residues available in each Broad Vegetation Group (BVG) on a per hectare basis following a sawlog only harvest. In the current report, logging residue was defined as the bark and crown components left after harvest, including unused stem wood that was too small or defective to be used as sawlog. Stump residues were excluded from the current study as it is unlikely that they would be extracted for use as biomass from hardwood native forest.

Ngugi et al. (2018) also estimated the potential biomass volume available from silvicultural treatments (thinning to remove small underperforming trees) in private native forest. This potential biomass source was excluded from the current report as silvicultural treatments, if performed at all, would be likely to occur in an ad hoc fashion on a small-scale. Ryan (2019) noted that the main barrier to increased silvicultural activity in Queensland's private native forest was forest owner

[2] https://environment.des.qld.gov.au/__data/assets/pdf_file/0029/85790/wr-eow-guideline.pdf

concerns that future legislative changes may remove or restrict their ability to harvest their forests. However, it should be noted that performing silvicultural treatments may increase the quantity of logging residues available in the future from private native hardwood forests in southern and central Queensland.

Based on the calculations of logging residues available for each BVG following a sawlog only harvest, the procedures used to estimate logging residues available on an annual basis for private and state hardwood native forest areas in the region covered by the current report are described in the following two sections.

7.2.1.1 Private hardwood native forest

Ngugi et al. (2018) reported on private hardwood native forest residues available from south-east Queensland only. To obtain estimates of the logging residue quantity for the study area, logging residue per hectare estimates for each BVG were multiplied by the area of commercially available private native forest in each BVG in the study area, obtained from Lewis et al. (2020). The commercially available area was estimated by Lewis et al. (2020) by reducing the total private native hardwood forest area in their study area by 5% to allow for stream buffers and by 1.2% to allow for areas >25 deg to comply with the "Managing native forest practice" code[3]. Lots of less than 20ha in area were also excluded as being too small to be managed for commercial harvesting. The boundary of the area covered by Lewis et al. (2020) excludes a small proportion of the private native forest along the western edge of the study area for the current report. However, the impact of this discrepancy on the estimates of private native hardwood forest logging residue would be minimal due to the small area of forest excluded and its relatively low productivity. The approximate harvestable area was calculated to be 1,900,000ha.

As only a small proportion of the total available sawlog resource in private native hardwood forests is currently harvested each year, a correspondingly small proportion of logging residue will be available on an annual basis. Private hardwood native forest harvest volumes are not reported separately and so were calculated by subtracting the native forest hardwood sawlog volume harvested from State Forest in Queensland[4] (149,372 m^3) from the total native hardwood sawlog volume for Queensland reported in ABARES 2021 (280,560m^3) giving an estimate of 131,188 m^3 of sawlogs harvested from Queensland private hardwood native forest in 2019-20 (the most recent data available). This represents 1.6% of the total available private native hardwood forest sawlog resource available and would produce approximately 210,000t of logging residues per year (oven dry weight).

The estimate of available logging residue refers to the quantity left on the ground in the forest after harvest, not all of which can be extracted to roadside, as residues that are thinly scattered or highly contaminated with dirt are left on site. The proportion of the available logging residues that could be economically extracted to roadside was assumed to be 36%, based on Thiffault et al. (2015). Therefore, the total estimated quantity of logging residues available at roadside is approximately 75,000 t per year (oven dry weight). Further losses occur when logging residue is chipped to increase its bulk density (it is uneconomic to transport unchipped logging residue) and screened. Screening

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[3] https://www.resources.qld.gov.au/__data/assets/pdf_file/0007/1446919/managing-native-forest-practice-code.pdf

[4] https://www.data.qld.gov.au/dataset/a6292b90-83ae-4fef-89b7-ee2093c7d10e/resource/084e7eeb-2aa4-4c2f-881e-8ec705004210/download/native_forest_timber_production_quantities_to_2019_20.csv

removes over or under-sized pieces which increases the quality of the logging residue for sale or further processing. In particular it can remove a large proportion of the soil and nutrient-rich fine material which can clog and corrode boilers (see Section 7.2.4). The magnitude of these losses is unknown for eucalypt logging residue, though overseas experience with coniferous logging residues found that losses were higher when the residue was dried prior to screening (Kuptz et al., 2019).

7.2.1.2 State hardwood native forest

Logging in State native hardwood forest in the eastern part of the study area is being phased out over the next two to four years, while logging in the western part will continue for the next 12 years. The approximate area currently available for harvest was calculated to be 2,000,000ha. Using the methodology described in the previous section, the quantity of logging residue available from State native hardwood forest would be approximately 240,000t per year (oven dry weight).

The proportion of the available logging residues that could be economically extracted to roadside was assumed to be 36%, based on Thiffault et al. (2015). Therefore, the estimated total quantity of logging residues available at roadside is approximately 86,000 tonnes per year (oven dry weight).

7.2.2 Hardwood plantations

The area of hardwood plantations in Queensland in relatively small compared with that in other Australian States (~18,000ha in 2019-20 (ABARES, 2021)) and hence harvest volumes and corresponding volumes of residues are small relative to those available from Queensland softwood plantations and native forests (Note that the area of hardwood plantations in Queensland was recently revised downwards by approximately 22,000ha due to the write-off of failed plantations (Department of Agriculture and Fisheries, 2021)). Harvest volume in 2019-20 was 27,800m^3 (ABARES, 2021) approximately 80% of which was used to produce export wood chips (ABARES, 2021). A range of species are grown in southern Queensland hardwood plantations with *Eucalyptus dunnii* and *Corymbia citriodora* being two major species (Legg et al., 2021). However, the species planted has not been recorded for the majority of the hardwood plantation estate area.

As there are no publicly available studies of the quantities and composition of logging residues retained on site after Queensland hardwood plantation harvesting, allometric relationships for *Corymbia citriodora* (Huynh et al., 2022) were used to estimate the logging residue quantity based on the harvest volume in 2019-20. The estimated total quantity of logging residue produced per year is approximately 12,000t (oven dry weight).

As there are very few studies of harvest residue extraction from eucalypt plantation harvest sites, the proportion given in Thiffault et al. (2015) for cut-to-length at the stump harvest operations was used (36%). The estimated quantity of logging residue available at roadside per year from hardwood plantations is 4400t (oven dry weight).

7.2.3 Total native hardwood forest & hardwood plantation logging residue

The total quantity of logging residue available at roadside from State and private native hardwood forests and from hardwood plantations was estimated to be approximately 165,400t per year (oven dry weight) (Table 2).

Table 2. Logging residue extractable to roadside from native forest hardwood forests and plantations in the study area (oven dry t/yr)

Forest/plantation	Harvestable area (ha)*	Extractable residue quantity (dry t/yr)
Private hardwood native forest	1,900,000	75,000
State hardwood native forest	2,000,000	86,000
Hardwood plantations	18,000	4,400
Total		165,400

* Native forest total areas were reduced by 5% for stream buffers and 1.2% for areas >25 deg. Lots <20ha excluded.

7.2.4 Potential uses of hardwood logging residues

It is unlikely that the logging residue available from native hardwood forests and plantations in the study area would be able to support large-scale industrial uses, such as bioenergy installations. A more detailed study may identify opportunities to supplement other feedstock sources or for other purposes such as biofuel or mulch in specific areas. The reasons for this conclusion were as follows:

- **Low spatial density (t/ha)** (This refers to the logging residue spatial density both within a stand and within a larger catchment area)

While the estimated annual native hardwood forest and plantation logging residue resource in the study area is reasonably high, it is spread over a large geographical area (>24 million ha), increasing secondary transport costs (from the roadside to the processor or customer). The low intensity (<10m^3 sawlog extracted per ha from most stands) selective harvesting conducted in native forests in the study area results in a low spatial density of logging residue within a stand which can increase primary transport costs (from the field to the roadside). Strandgard et al. (2021) found that the combined cost of primary and secondary transport of logging residue at low spatial densities could >16% higher than when it was available at higher spatial densities. Roadside storage can be used to buffer the flow of logging residue while also reducing transport costs and improving fuel quality, but requires loading equipment and trucks to return to the site and an additional level of monitoring and management of the logging residue piles during storage.

The impact on transport costs of the low spatial density of logging residue in the study area is compounded by the low energy and bulk densities of logging residues which requires considerably larger quantities of material to be delivered to achieve the same energy yield as fossil fuel sources.

- **Low quality biofuel**

The main international standard for solid biofuels is the ISO standard EN ISO 17225. The quality of solid biofuels is defined in terms of its physical (size, moisture content, etc) and chemical characteristics (ash content). Ash content is a key woody biofuel quality determinant as higher ash content increases corrosion and fouling of boiler equipment and toxic emissions (Toscano et al., 2020). Eucalypt logging residues can potentially have a high mineral and chlorine content due mainly to high concentrations in leaves and bark (Pena-Vergara et al., 2022). Hence, eucalypt logging residue is likely to produce lower quality, and hence lower value, biofuel. As noted above, fuel quality may be improved through screening logging residue after chipping, however, this also reduces the quantity of fuel produced.

- **Uncoordinated forest management decisions**

In the case of private native hardwood forests, harvesting decisions are currently largely made by individual landholders to meet their own objectives. This results in a relatively unpredictable availability of logging residues, making it difficult for a potential user of the resource to plan their operations. Stockpiling at the customer's facility can alleviate this problem to an extent, however, large piles of chipped logging residue can be very difficult to extinguish if they catch fire through spontaneous combustion or from embers from bushfires.

Recommendation

The formation of regional forest owner co-operatives could provide more certainty in logging residue flows and may also be a means of promoting improved forest management. Forest owner co-operatives are common in Nordic countries (Norway, Sweden, Denmark and Finland) where they negotiate prices on behalf of owners and assist with management advice.

7.3 Softwood plantations

In 2019, there were approximately 161,000ha of softwood plantations in southern Queensland, 160,000ha of which were managed by Hancock Queensland Plantations (HQP) (Department of Agriculture and Fisheries, 2021). The HQP southern softwood plantations consist of approximately 120,000ha of southern pines and 40,000ha of Araucaria. The majority of the softwood plantations in southern Queensland are located within 100km of Gympie. This concurs with the findings of Van Holsbeeck et al. (2020) who identified a location near Gympie as the optimum location in Queensland for a bioenergy facility. The estimated quantities of logging residues available are ~70 green metric tonnes per hectare (GMt/ha) in the southern pine plantations (based on Berry (2019), Simpson et al. (2004)) and ~300GMt/ha in Araucaria plantations (based on Costantini et al. (1997)). The percentage of available logging residue that could be extracted to roadside was assumed to be 54%, based on Thiffault et al. (2015). Estimates of logging residues extractable annually are in Table 3. Note that these residue quantities are estimates as there is considerable variability in residue quantities between sites resulting from a range of factors, including site productivity, stand age at harvest, stocking, silviculture, degree of stem defects, utilisation standards, operator skill, etc.

Table 3. Quantities of logging residue extractable to roadside from HQP softwood plantations (Southern pine and Araucaria) in the study area (oven dry t/yr)

Species	**Plantation**	**Extractable residue quantity (dry t/yr)**
Southern pine	Beerburrum	14,500
	Tuan/ Toolara / Wongi	50,000
SP total		64,500

Araucaria	Mary Valley	15,400
	Central Range	18,400
	Blackbutt / Yarraman	26,000
Araucaria total		59,800
Total residue		124,300

A number of factors favour lower delivered costs for logging residue from Queensland's softwood plantations compared with native hardwood forests and plantations, in particular the large contiguous plantation areas and the predominance of roadside processing. These factors minimise both primary and secondary transport costs through high spatial density of logging residue on a regional and stand level. Removal of logging residue can also reduce site preparation costs (see Section 7.3.2).

Southern pines have a high resin content which can be extracted to produce terpenes and rosin (Harrington, 1969). The potential southern pine stump resource was estimated to be 200,000 tonnes per year, though not all of this resource would be economically harvestable. This calculation was based on the assumptions that 3% of the softwood plantation is harvested per year (3600ha) and that the final stocking is 400 stems per hectare and that each stump weighs 140kg (based on a stump harvesting study in *Picea abies* (Laitila et al., 2008)).

7.3.1 Potential uses of softwood logging residues

A proportion of the logging residue from HQP's southern pine plantations is currently being harvested from areas where trees were processed at roadside. The logging residue harvested consists of stem sections that do not meet current utilisation standards (too short, thin or defective). The logging residue is chipped and screened to produce a variety of products including biofuel, animal bedding and playground surfacing. Its use as feedstock for other industries, including particle board and wood pellet manufacture, is being considered. HQP expect to considerably increase the proportion of this resource being used over the next few years.

Leaf Resources (leafresources.com.au) plan to extract terpenes and rosin commercially at an upgraded plant near Bundaberg using southern pine logs that are too resinous to produce sawn products and stumps from HQP's southern pine plantations. Amongst other uses, the major volatile component of southern pine oleoresin, turpentine, can be used as a component of the fuel in diesel engines in mixtures containing up to 75% turpentine (Karthikeyan and Mahalakshmi, 2007). Chipped wood remaining after chemical extraction would be shipped overseas for use as biofuel. Initial plans are to process 100 tonnes of logs and stumps per day. Assuming 200 days of operation per year, the annual throughput of logs and stumps would be approximately 20,000 tonnes. Based on the assumed availability of southern pine stumps per year of 200,000 tonnes, there is considerable scope for expansion of terpene and rosin production from stumps, subject to market demand. However, transport cost increases to supply the additional stump biomass will limit the economic viability of increasing the supply.

Potential alternative uses for southern pine logging residues include integrated harvesting of below small end diameter (SED) specification crown wood, production of biochar and extraction of pine oil through steam distillation (Kelkar et al., 2006). Extraction and use of non-stem logging residue may incur high costs to upgrade to the required degree (comminution, screening, drying, etc) depending on the desired end-use. There are no publicly available analyses of chipping and screening logging residue from Australian harvesting operations. Figure 2 shows chipped coniferous logging residues in Austria before ((a).) and after ((b).) screening (Kuptz et al., 2019). Screening was performed after drying and removed particles >45 mm and <20 mm. As can be seen, there was still a large proportion of bark and twigs remaining after screening.

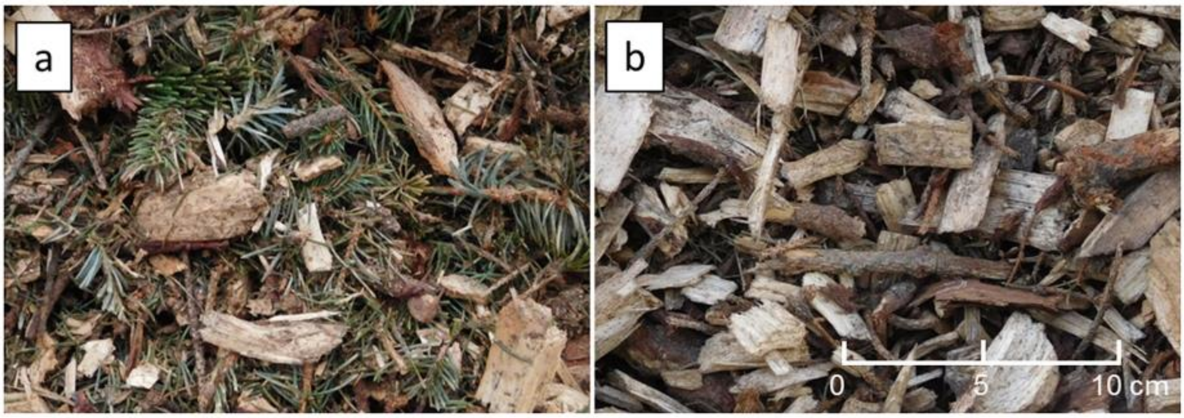

Figure 2. Chipped coniferous logging residue in Austria. (a). Fresh chips; (b). Chips screened after drying to remove material >45 mm and <20 mm (Kuptz et al., 2019).

Unused crown stem and defective stem sections represent a potential source of clean wood for chipping. Alternatively, reducing the current SED specification would allow a greater proportion of the crown stem wood to be extracted as chip logs during normal harvesting operations, rather than as a separate operation. Berry (2019) found that there was 37GMt of stem wood with a minimum large end diameter of 3cm remained on a high productivity southern pine cut to length at the stump harvest site in southern Queensland. The minimum stem diameter that a harvester head can handle would be a factor in determining how much additional crown stem wood can be extracted. Reducing the SED specification must be coupled with exploitation of the full range of allowable chip log lengths. A study of chip log length distributions conducted by Hancock Victorian Plantations found that harvester operators were preferentially cutting chip logs to 5.8m, the size that best fitted on a truck, whereas the pulp log length specification allowed lengths between 3.7m – 6.0m. Losses of potential chip wood were substantial.

Biochar (carbonised biomass) can be used as a soil conditioner and a long-term carbon store. It is often promoted as a potential use for forest and sawmill residues but there are few commercial producers in Australia and the overwhelming majority use non-forest biomass. Van Holsbeeck (2018) suggested that there was a large potential logging residue resource (combining native hardwood and softwood residues) within 50km of the existing Pyrocal biochar plant (www.pyrocal.com.au) at Wellcamp near Toowoomba that could theoretically be processed at this plant. In a study of the commercial viability of biochar from woody biomass, Campbell et al. (2018) found that, while biochar prices varied from under US$100 to over US$10,000 (due mainly to differences in quality and post-conversion treatments), net agricultural benefits only accrued for prices at the lowest and of the scale. However, the authors noted that the ability of biochar to sequester carbon for extended periods could increase its value if there was a market for this service.

Pine oil is an internationally traded product with a wide range of uses that commands a high market price. In a desktop study of the potential for pine oil production from *Pinus ponderosa* logging residue, Kelkar et al. (2006) note that further investigation would be required into the chemical yields, quality, production costs and market demand to determine the commercial viability of pine oil extraction from logging residue. The relatively low delivered costs of southern pine logging residues from roadside processing operations would be an advantage in achieving low pine oil production costs.

Of these potential alternative uses for softwood logging residues, decreasing the SED for pulp logs has the highest potential as it can be done using existing harvesting, transport and processing equipment. Detailed further analyses would be required to determine the commercial viability of biochar or pine oil production.

7.3.2 Site preparation cost reductions

A large component of post-harvest site preparation typically involves treating logging residues (e.g. burning, chopper-rolling, heaping) to allow subsequent site preparation and planting activities to occur. Berry (2019) found that in addition to potential revenue from sale of logging residues from HQP's southern pine plantations, there could be savings in reduced site preparation costs of up to $600/ha on typical harvest sites due to the reduction in logging residue quantities.

7.4 Primary processor residues

7.4.1 Sawmills

Processing sawlogs to sawn timber produces a considerable quantity of sawdust, chips, shavings, offcuts and bark. The percentage of sawlogs converted to sawn timber in Queensland (the recovery rate) is on average: hardwood 42.3%; softwood 48% (Downham et al., 2019). The higher recovery rate in softwood sawmills compared with that in hardwood sawmills is related to a wide variety of factors, including log diameter, length, taper, and quality, type and condition of scanning and sawing machinery, product mix and operator decision making (Steele, 1984). Total sawmill residues produced per annum in Australia are: hardwood ~1.09 million m^3; softwood ~4.4 million m^3 (Downham et al., 2019). As a by-product of the production of sawn timber, quantities of sawmill residue produced are driven by demand for sawn timber, which may not match demand for the residues. Based on harvest volumes and the recovery rates above, estimated total sawmill residues produced each year in the study area are:

- Native hardwood forest (public and private) ~163,000m^3 (Hardwood plantation sawmill residues were excluded as 80% of the wood produced is exported as woodchips).
- Southern pine plantations ~670,000 m^3
- Araucaria plantations ~180,000 m^3

Sawmills have increasingly been treating timber onsite with a variety of preservative chemicals (Table 4), resulting in increasing quantities of treated timber waste being produced from sawmills.

Table 4. Timber hazard levels, typical uses and preservative currently used for each hazard level (based on the table in https://www.epa.nsw.gov.au/-/media/epa/corporate-site/resources/household-building-and-renovation/treated-timber-chart.pdf)

Hazard level	Exposure	Typical uses	Preservative currently used for hazard level
H1	Inside, above ground	Borer susceptible hardwood used for dry interior framing, flooring, furniture and joinery	Boron
H2	Inside, above ground	Framing, flooring, joinery, etc. used in interior dry situations	Boron (south of the Tropic of Capricorn only), synthetic pyrethroids, imadacloprid
H2F	Inside, above ground	Framing used in interior dry situations (south of the Tropic of Capricorn only)	'Blue Pine' (synthetic pyrethroids, imadacloprid)
H2S	Inside, above ground	LVL/Plywood (glue-line treatment) in dry situations (south of the Tropic of Capricorn only)	Synthetic pyrethroids, imadacloprid
H3	Outside, above ground	Weatherboard, fascia, pergola posts (above ground), window joinery, framing and decking	ACQ, CA, CCA (not residential decking), LOSP
H3A	Outside, above ground (protected by paint)	Fascia, bargeboards, exterior cladding, decking, window and door joinery and veranda posts	LOSP
H4	Outside, in-ground	Landscaping timbers, fence posts and pergola posts (in-ground)	ACQ, CA, CCA, creosote (farm fencing only)
H5	Outside, in-ground, contact with or in fresh water	Retaining walls, piling, house stumps and building poles	ACQ, CA, CCA, creosote (power poles)
H6	Marine waters	Boat hulls, marine piles and jetty cross bracing	CCA, creosote (in waters above Batemans Bay only in combination with CCA)

ACQ: alkaline copper quaternary

CA: copper azole

CCA: copper chrome arsenate

PEC: pigment emulsified creosote

LOSP: light organic solvent preservative

LVL: laminated veneer lumber

7.4.2 Potential uses of untreated sawmill waste

Of the waste streams covered in this report, sawmill residues are the most highly sought after as they have relatively low transport costs, have been processed to an extent, have a low degree of contamination and some residues (particularly sawdust and shavings) have a lower moisture content than green timber.

Queensland native hardwood sawmills process on average less than 10% of the log volume annually than softwood sawmills and in total process approximately 20% of the log volume that softwood sawmills process (Downham et al., 2019). As such, waste from softwood sawmills represents a more attractive resource in terms of potential uses than does the waste from native hardwood sawmills. Native hardwood sawmills (Appendix 3.1) are also more dispersed geographically than softwood sawmills (Appendix 3.2), increasing the costs of aggregating their waste. In contrast, the majority of the southern pine sawmill waste is produced by three sawmills: the Hyne sawmill at Tuan, the AKD sawmill at Caboolture and the Allied Timber Products sawmill at Burpengary and the majority of the Araucaria sawmill waste is produced by the Superior Wood sawmill at Imbil.

In Queensland, the recent introduction of a waste levy[5] has increased the financial incentive to find alternative uses for material previously sent to landfill. The major waste product produced from sawmilling (>50%) is wood chips. Softwood woodchips in Queensland are used in particle board and MDF manufacture, exported for use in paper manufacture or as fuel, or used for landscaping. Native hardwood woodchips are primarily used for landscaping. While there are other potential uses, such as hardboard manufacture and export woodchips, the dispersed resource, low demand for pulp from the species available and competition from imported products is likely to make these options commercially unviable. Similarly, addition of native hardwood woodchips to existing particle board and MDF manufacturing processes is likely to increase production costs due to the differences in hardwood and softwood wood properties.

Sawmill waste (sawdust, shavings and offcuts) is used for energy production to meet the needs of sawmills to generate heat for kiln drying, and to produce pellets, briquettes and firewood (see section 7.4.2.1 for more detail). Sawdust and shavings are also used as a component of compost and mulch for soil amendment and as animal bedding. Increased fertiliser prices and potential restrictions on application of nitrogenous fertilisers to reduce greenhouse gas emissions, may increase the demand for sawdust and shavings for soil amendment.

Pine bark is commonly used in Australia in the production of potting mixes. Hardwood logs are delivered to hardwood mills debarked. Pine bark can also be burnt as biofuel, however it has a high mineral content which can cause fouling and corrosion of boilers. Xavier et al. (2021) suggested that phenolic compounds could be extracted from pine bark prior to its use for other purposes. Pine bark phenolic compounds have antioxidant and antimicrobial properties and have the potential to be used for adhesives in engineered wood products.

7.4.2.1 Valorisation of sawmill waste as biofuels and bio-based products

Untreated wood waste can be used to produce either solid (including firewood, shavings, sawdust, wood chips and wood pellets), gaseous (including biomethane and syngas) or liquid biofuels (including bioethanol, biodiesel). Co-location of a biofuel plant at a sawmill allows surplus heat from the plant to be used in the sawmill, which can be a major factor in the financial viability of the biofuel plant (Ahlström et al., 2017). The world-wide movement to a circular bioeconomy also provides opportunities for export of biochemicals to replace those derived from fossil fuels. An

[5] https://www.qld.gov.au/environment/management/waste/recovery/disposal-levy/about/overview (Accessed 7th June 2022)

example of this is an industrial solvent (Cyrene™) produced by Norske Skog in Tasmania from radiata pine sawdust. Before the wood waste can be used as a resource in Queensland it may need an EOW code to be developed, as described in Section 6.1.

7.4.2.1.1 Solid biofuels

Sawmill waste can be used directly as fuel. Hardwood sawmills often sell offcuts as firewood. Sawmills that require heat onsite may use sawdust as boiler fuel. As wood chips can be used for either biofuel or paper manufacture or other purposes, the quantity available for use as biofuel will depend on the market for competing uses (Lock and Whittle, 2018). The advantage of using sawmill waste directly as a fuel is avoidance of the capital costs and ongoing costs from building a processing plant. The disadvantages are that sawmill waste has a relatively low energy density, increasing its storage and handling costs, and transport costs if not used on the sawmill site. Sawdust can also form explosive mixtures with air at relatively low concentrations (Liu et al., 2019). Accordingly, direct use of sawmill waste as an industrial biofuel typically occurs onsite or at a nearby plant, while densification of sawmill waste into briquettes or wood pellets allows the biofuels to be economically transported internationally. Use of sawmill waste for energy production onsite has in the past been most attractive to larger sawmills due to their better economies of scale. However, recent fossil fuel price increases have made substitution of sawmill waste for fossil fuels, more attractive to a broader range of sawmills.

Briquettes are cheaper to produce than wood pellets because the raw material is less refined and less energy is required to operate the briquetting press (Stolarski et al., 2013). However, international trade in wood pellets is considerably greater than that in briquettes because wood pellets are easier to handle as their flowability is similar to that of grains, burn easier due to their higher surface area and can be used in both domestic and industrial applications, whereas briquettes are primarily used in industrial applications (Bajwa et al., 2018).

The energy density and stability of wood pellets can be improved by heat treating the input material prior to pressing (torrefaction) (Peng et al., 2015). However, the additional costs involved to produce torrefied pellets often outweighs their advantages in transport and storage costs compared with untorrefied (white) wood pellets (Agar, 2017).

Production of export wood pellets represents an opportunity for use of Australian woody waste as the market is expanding due to commitments to reduce greenhouse gas emissions and, more recently, price increases for fossil fuels used for electricity production. Sawmill waste is the cheapest woody waste material to produce wood pellets, in particular mixes of sawdust and shavings (Visser et al., 2020) due to their low initial moisture content and their need for limited additional processing. In Queensland, Altus Renewables use waste from the Hyne Tuan sawmill and the AKD Caboolture sawmill (85% sawdust & 15% shavings) to produce wood pellets. Leaf Resources and AKD Caboolture are in the process of setting up onsite wood pellet production facilities to increase the value of their own waste materials.

South Korea and Japan are the main consumers of wood pellets in the Australian region. The South Korean and Japanese markets for wood pellets have been growing rapidly in recent years, providing a good opportunity for Australian suppliers. However, there have been increasing supplies of wood pellets from countries closer to South Korea and Japan than Australia (Vietnam, Malaysia, and Indonesia) and further afield from Canada and the USA. Export of wood pellets to Europe may represent another opportunity for Queensland wood pellets as demand there has increased due to increased fossil fuel costs combined with restrictions on supply in addition to mandates to supply energy from renewable sources. Although some shipments of wood pellets have been made to Europe from Queensland, international shipping costs are predicted to remain high, increasing transport costs to Europe.

7.4.2.1.2 Gaseous and liquid biofuels

Sawmill waste can be used to produce gaseous or liquid biofuels. Biomethane is typically targeted as a gaseous biofuel in the published literature as the production process is more efficient (in terms of the proportion of energy in the original biomass converted to energy in biofuel) than that for liquid biofuels (Tunå and Hulteberg, 2014) (Table 5) and it can be readily incorporated into existing natural gas distribution systems. However, the cost of producing biomethane is substantially higher than fossil methane (natural gas). Ahlström et al. (2017) estimated the production cost of biomethane produced at a large sawmill (500,000m^3/yr sawnwood output) to be 68–82 EUR per MW h, compared to the average Swedish price of natural gas for industrial users in 2015 of 34 EUR/MW h. In Australia biomethane is mainly produced commercially from landfill and sewage. Electricity produced from biomethane in 2016/17 was 1,200 GWh (4,320 TJ), or 0.5 per cent of Australia's electricity generation (Carlu et al., 2019). There has been little interest in Australia in production of biomethane from woody biomass.

Table 5. Summary of energy conversion efficiencies for a range of biofuels produced from woody biomass (from Tunå and Hulteberg (2014)).

	Biomethane	Biomethanol	Biodiesel	Bioethanol
Energy[a]	66.50%	58.70%	45.60%	41.20%
Electricity[b]	3.50%	1.80%	5.90%	0.10%
District heating[c]	23%	0.36%	13%	0%
Losses[d]	7.30%	39.10%	35.50%	58.70%

a - % of woody biomass energy converted to product energy (MJ/MJ)
b – electricity generation from heat generated during production
c – heat suitable for district heating generated during production
d – energy losses during production

Production of liquid biofuels from sawmill waste (and logging residues) is often suggested in the published literature as a means to upgrade this material to higher value products that can be used as "drop in" replacements for fossil fuel transport fuels. Replacement of fossil fuels with liquid biofuels could reduce Australia's greenhouse gas emissions and reliance on imported oil.

Queensland has a biofuel mandate for bioethanol and biodiesel which requires fuel sellers to sell minimum quantities of each of these biofuels. Currently the minimum requirements are 4% bioethanol by volume of regular unleaded petrol sold and 0.5% biodiesel by volume of diesel sold. At this stage, the bioethanol mandate is being met from fermentation of sugar cane and wheat waste while the biodiesel mandate is being met from esterification of predominantly waste cooking oil plus animal fat and vegetable oil. Production of bioethanol and biodiesel from sawmill waste (or logging residues) is more complicated than the current production methods for these fuels, particularly in the case of biodiesel, resulting in the delivered costs for liquid fuels produced from sawmill waste being considerably greater than those currently available. For example, bioethanol from woody waste was estimated to cost 0.80 – 1.20 USD/l to produce compared with 0.20 – 0.53 USD/l when produced from sugar or starch containing crops (Bušić et al., 2018) while Kargbo et al. (2021) estimated that production costs of liquid biofuels from lignocellulosic sources were approximately twice those of the fossil fuel equivalents. As such, it is unlikely that bioethanol or biodiesel produced from sawmill waste would be economically viable unless production costs were reduced and/or the quantity of biofuel required to meet the mandate exhausted supplies of lower cost feedstocks.

A number of other liquid fuels have been put forward as options for biomass-derived transport fuels, though they also have a higher cost than fossil fuel alternatives. Of these, biomethanol is the most promising as it is cheaper and more efficient to produce from woody waste than bioethanol (Tunå and Hulteberg, 2014) (Table 5). Bio-oil can also be produced from sawmill waste using fast pyrolysis with high yields (75%) and can be used as a biofuel or chemical feedstock. However, as a biofuel it has a number of undesirable characteristics, in particular it is incompatible in its raw state with existing transport fuels (Goble and Peck, 2013).

An overview of the steps involved in producing biodiesel, bioethanol and biomethane from wood waste is shown in Figure 3. The steps involved in producing bioethanol from sugarcane and biodiesel from waste oil/fat are also shown for comparative purposes.

Bioethanol and biodiesel sold under the Queensland biofuels mandate must also meet the sustainability criteria for biofuels:

- a greenhouse gas assessment that requires unblended biofuels, regardless of the feedstock, to deliver greenhouse gas savings of at least 20% when compared to regular petrol or diesel
- a certification under the relevant environmental sustainability standard specific to the relevant feedstock.

Production of liquid biofuels using logging residue as feedstock would meet these standards.

7.4.2.1.3 Biochemical production

While there are hundreds of bio-based chemicals and feedstocks that can potentially be produced from sawmill waste, the production processes for many of these substances are under active investigation. For more information on potential bio-based substances, refer to Nattrass et al. (2016).

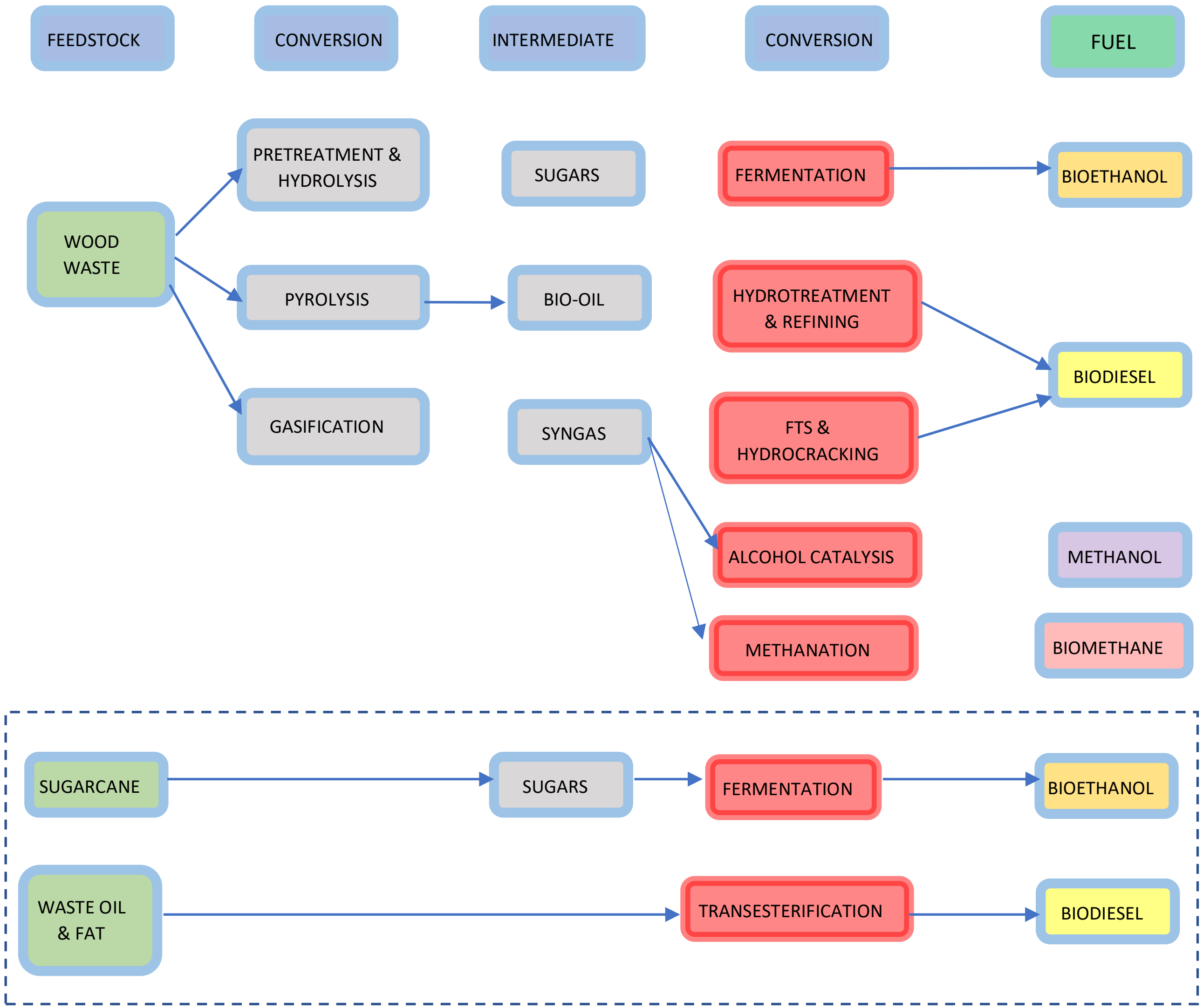

Figure 3. Overview of steps involved in the production of bioethanol, biodiesel, methanol and biomethane from wood waste. Production of bioethanol from sugarcane and biodiesel from waste oil/fat are shown for comparative purposes. (Adapted from E4tech (2017)).

7.4.3 Potential uses of treated sawmill waste

See section 7.5.4.

7.5 Landfill waste diversion

The most recent reporting of the types and quantities of unused municipal solid waste (MSW), commercial and industrial (C&I) waste and construction and demolition (C&D) waste going to landfill in Queensland is from 2017/18[6]. This report is based on a very limited number of compositional audits performed of waste streams going to landfill, most of which were conducted on MSW waste with only one performed on C&D waste. Annual Queensland government Recycling and Waste reports (the only publicly available source of data for these waste streams) in subsequent years only provide the aggregated waste recovery percentage for each of the three waste stream categories, so the quantity of unused waste timber going to landfill is unknown. It is likely that a considerable proportion of the waste in these reports is generated in Brisbane's urban areas however the data for Brisbane is combined with that for the neighbouring municipalities included in the scope of these reports. An up-to-date audit of the components of Queensland MSW, C&I and C&D waste streams is required to determine the quantities and locations of unused timber and other waste materials that could potentially be recovered. There have also been no chemical analyses conducted of waste streams in Queensland that can be used to estimate levels of chemical treatments and contamination from paint, varnish, etc in waste timber. In the absence of Queensland data, a chemical analysis of NSW C&D mixed waste stream[7] will be used to indicate potential levels of contamination could be found in Queensland C&D waste.

Within the study area, a major limitation to increasing the levels of waste materials diverted from landfill or transfer sites is the low levels of infrastructure, staff and/or space required to sort and store the recovered materials[8].

7.5.1 Municipal solid waste

Household waste collected from kerbside contains very low proportions of wood (<5%) whereas household waste dropped off at transfer stations by residents has been found to consist of approximately one third timber including treated, painted and untreated timber, furniture. The total quantity of wood contained in MSW arriving at landfill or transfer stations in Queensland was estimated to be ~200,000t[8]. This may be a source of clean, recyclable timber but is likely to require manual separation which is unlikely to be cost-effective except for high-value items such as those listed in section 7.5.3.

The proportion of woody material in garden waste has not been reported in any Australian publication found in the literature searches for the current study. Any woody material will also be mixed with a variety of other green waste and a level of contamination from material used to tie green waste bundles as well as other waste accidentally or deliberately added.

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[6] https://www.qld.gov.au/__data/assets/pdf_file/0034/199249/qld-waste-resource-recovery-infrastructure-report.pdf

[7] https://www.epa.nsw.gov.au/-/media/epa/corporate-site/resources/waste/070320-constr-demol-waste2.pdf?la=en&hash=6378AA7296D9E01511CBBD2765F7824B60F2F166

[8] https://www.qld.gov.au/__data/assets/pdf_file/0034/199249/qld-waste-resource-recovery-infrastructure-report.pdf

7.5.2 Commercial and industrial waste

Commercial and industrial (C&I) waste includes any waste which is generated by a business or institution. The total quantity of woody waste in the Queensland C&I waste stream was estimated to be 500,000t[8]. Waste from primary and secondary wood processors is likely to be captured in this waste stream as well as wooden pallets, packaging and cable reels. In 2017-18, organics processors in Queensland recovered 137,200 tonnes of sawdust, wood and timber waste mainly to produce soil, potting mix and soil conditioners[9]. While the components of this stream were not broken down in the report, it is understood that the majority consisted of sawdust. In 2019-20, there was a substantial increase in the quantities of woody waste recovered by organic processors consisting of 275,000t of sawmill residues (again believed to be largely sawdust) and 58,000t of timber, wood and sawdust[10]. The majority of this waste was processed in SE Queensland, though the proportion generated in this region was not stated. The reason for the substantial increase in woody waste processed by organic processors was not stated but is possibly due to the introduction of the waste levy, greater availability of timber and sawmill waste, greater demand for soil-related products or other factors. The scope for further use of C&I wood derived waste by Queensland organic processors is limited due to the lack of available production capacity and the lack of demand for their products[11].

Other potential uses for C&I wood waste include, animal bedding, particle board feedstock and as fuel.

7.5.3 Construction and demolition waste

The introduction of the waste levy in Queensland reduced the quantity of C&D waste sent to landfill from over 2 million tonnes in 2018/19[9] (prior to the levy introduction) to under 1 million tonnes in the following year (2019/20)[10]. The majority of the recycled material was concrete, ferrous metals and asphalt due to their weight, which results in greater landfill cost savings, their consistency and their established recycling processes and end markets. Approximately 8% of timber waste was recycled in 2017/18. The recovery of the concrete, ferrous metals, asphalt and other materials from the C&D waste results in a large proportion of the material being sent to landfill consisting of waste wood. In 2017/18, over 330,000t of C&D waste wood was sent to landfill in Queensland.

Separation of wood and other recyclable materials during construction and demolition would enable greater recovery of materials. This currently occurs on larger demolition sites for masonry, concrete, metals and, to a lesser extent, wood. For smaller demolition jobs, such as houses, the considerably greater time required to deconstruct rather than demolish a house (up to twice as long[12]) makes it cheaper in many instances to mix all waste into the same skips. The exception to this is for high value items from older houses, such as, floorboards, doors and period features. Large timber pieces are also typically salvaged during demolition of older industrial buildings, bridges and wharves, and the replacement of railway sleepers and utility poles as there is a ready market for large dimension timber, particularly hardwood timber, which is used for large beams or re-sawn into a variety of

[9] https://www.qld.gov.au/__data/assets/pdf_file/0021/93711/recycling-waste-qld-report-2018.pdf
[10] https://www.qld.gov.au/__data/assets/pdf_file/0044/198989/recycling-waste-report-2020.pdf
[11] https://www.dcceew.gov.au/sites/default/files/documents/australian-organics-recycling-industry-capacity-assessment-2020-21.pdf
[12] https://www.epa.nsw.gov.au/-/media/epa/corporate-site/resources/managewaste/100082-roof-timber-removal.pdf?la=en&hash=82A9CC5882F0B323F55A46B5EAD71826F1B76490

products. Separation of mixed C&D waste at receiving facilities can also be used to extract recyclable materials but is largely targeted again at masonry, concrete and metals with timber making up a large proportion of the remaining material going to landfill.

Construction timber waste represents a potential source of relatively clean timber, though it will also contain a proportion of metal fasteners, engineered wood products and H2F treated timber. The most significant barrier to increased recycling of residential construction wood is that the majority of residual construction is performed across numerous sites by small to medium companies with few staff and tight margins. Space in residential building sites is generally limited leading to use of a single skip for all waste. Larger building sites have the potential to separate different waste types at source. However, there are no data on the quantity of waste recovered from construction. The estimate of waste timber from house construction in the study LGA's in 2020/21 was 8900m^3. This was based on ABS dwelling construction data (15788 dwellings) and estimates of 4% waste in dwelling construction and 14.1m^3 of timber per dwelling in Kapambwe et al. (2008). Kapambwe et al. (2008) took into consideration that half of the offcuts generated during construction were re-used onsite, mainly for noggins and packers and blocks in the frame.

Timber in older dwellings may have been treated with any of a large number of possible chemical treatments, including treatments no longer permitted to be used for this purpose. Timber from older dwellings may also have been coated with a variety of possible paints or varnishes, including lead-based paints. For buildings constructed prior to 1990, there is also the possibility of asbestos contamination as asbestos was widely used to make wall and floor sheeting, roofing and pipes. As the life span of a dwelling in Australia is approximately 60 years (Kapambwe et al., 2008) and the widespread use of H2F treatment for timber used in house construction is relatively recent, the proportion of H2F timber in demolition waste is currently very low.

The heterogeneity of wood recovered from C&D waste, in terms of particle size, hardwood or softwood, unknown proportions of treated or painted timber, engineered timber containing glues or resins and contamination with other material, limits its potential use to energy recovery. Fine material (<4.75mm particle size) can make up 20% of C&D waste[13] and is likely to contain contaminants such as sand and soil that can foul or corrode boilers requiring its removal through screening before use as fuel.

7.6 Chemically treated timber waste

As noted in section 7.5, there are no publicly available chemical analyses of Queensland wood waste streams. An audit of C&D waste in NSW[13] found that, whereas CCA treated timber made up a small proportion of the C&D wood waste at landfill (4% of samples analysed), the high concentrations of copper, chromium and arsenic in the CCA waste (from 300mg/kg to over 3000mg/kg) raised the mean levels of these metals in the wood waste to over 70mg/kg compared with natural background levels of under 3mg/kg. Similarly, for lead and zinc, and to a lesser extent mercury and cadmium, demolition timber from old buildings contained considerably greater levels of these metals than timber from new constructions due to the presence of paint and varnish containing these compounds. Approximately 2% of the samples analysed contained unacceptably high lead levels. Interestingly, the study found that waste wood that was sourced from a material recovery facility

[13] https://www.epa.nsw.gov.au/-/media/epa/corporate-site/resources/waste/070320-constr-demol-waste2.pdf?la=en&hash=6378AA7296D9E01511CBBD2765F7824B60F2F166

had considerably lower levels of lead, zinc, mercury and cadmium, probably due to mechanical abrasion of surface coatings during the recovery process.

Currently in Australia, there are a wide range of timber treatments in terms of the chemicals applied and their toxicity, the concentrations of these chemicals and the depth of penetration of the chemical into the timber (Hann et al., 2010). However, guidelines regarding disposal of treated timber rarely distinguish between timber treatments. In most cases, the recommendation from regulatory authorities and treated timber suppliers is to dispose of all treated timber in landfill. This is likely to be a response to the potential for impacts on human health from exposure to arsenic and chromium in particular from copper chrome arsenate (CCA) treated timber and the danger of releasing toxic particles through burning CCA treated timber or from the remaining ash (Morais et al., 2021). Australia and New Zealand were, per capita, the greatest consumers of CCA treated timber in the world. Recent changes in Australia no longer allow CCA treated timber to be used in Australia for structures where people are likely to come in frequent contact with the timber, including garden furniture, picnic tables, exterior seating, children's play equipment, patio and domestic decking, and handrails. Allowable uses for CCA treated timber include power poles, landscaping and jetty piles. However, there are still large quantities of CCA treated timber in use that can potentially enter the waste stream. Alkaline copper quaternary (ACQ) and Copper Azole (CA) are timber treatments that can be used instead of CCA for timber exposed to H3, H4 or H5 hazard levels (Table 3).

A major issue with unsorted waste such as household green waste and construction and demolition waste, is separating treated and untreated timber. Visual inspection relies on considering the previous use (decking, fencing, poles and posts), looking for treatment tags and looking for coloured dyes that indicate wood treatment (Rasem Hasan et al., 2011). However, dyes can fade due to weathering or be obscured with dirt. Manual application of stains, test kits and handheld detectors can also be used but are typically not suitable for processing large quantities of wood waste due to the time required to test each piece of wood (see Rasem Hasan et al. (2011) for examples). Online tests that are suitable for detecting and separating treated timber from large quantities of mixed waste on a conveyor belt concentrate on detecting heavy metals (Arsenic, Copper, Chromium), can miss up to 15% of CCA treated timber pieces and cost up to US$35/ton of wood processed to build and operate (Rasem Hasan et al., 2011).

The half-life in soil of synthetic pyrethroids used in H2F timber treatment is typically several weeks but can vary considerably depending on the soil constituents and environmental conditions and on the micro-organisms present in the soil (Cycoń and Piotrowska-Seget, 2016).

7.6.1 Potential uses of chemically treated timber waste

The recent introduction of a waste levy in Queensland, combined with a lack of options for using chemically treated timber waste is incurring considerable costs from the waste levy, landfill fees and from transport costs to landfill sites which accept treated timber waste. However, the high costs in turn create an incentive for reuse and recycling as companies can charge a lower fee for collection of treated timber waste than the current disposal costs in order to cover their costs. A major obstacle to the diversion of treated timber waste from landfill is the precautionary approach taken by regulatory authorities noted in section 7.5 whereby they recommend that all waste treated timber be disposed of in landfill.

A range of chemicals are currently used to treat timber. These chemicals can be applied individually or in combinations and in differing concentration levels. The depth of chemical penetration into timber can also vary depending on the application. The chemicals also vary in their toxicity to plants, animals and humans. Waste demolition timber may also have been treated using chemicals that are no longer permitted to be used for this purpose.

As outlined in section 6.1, in Queensland the process to legally allow use of any waste material, including treated timber, as a resource requires the development of an EOW code or approval. At the time of writing there were two EOW codes and no EOW approvals relating to the use of treated timber as a resource. The EOW codes cover the following wastes and resources:

- The use of ACQ shavings as a component of no more than 5% in the manufacture of compost or mulch[14]
- The use of chemically treated solid timber to manufacture engineered wood products or dimensioned timber products[15]

The EOW code allowing the use of ACQ treated timber shavings in mulch can be used by existing producers of ACQ treated timber, or, as suggested by Troy Justice (LSI), allow timber treatment facilities to commence production of ACQ treated timber to take advantage of the existing EOW code[16]. Although there is not a current EOW code for use of other forms of treated timber for mulch, an EOW code similar to that for ACQ treated timber could potentially be created for waste wood treated with copper azole.

Depending on the depth of treatment penetration and the timber dimensions, the treated volume amounts of chemical treatment (only the outer few millimetres of wood receive treatment) and the short half-life in soil of the chemicals used in H2F treatment, suggests that a submission for an EOW code for the use of H2F treated timber waste as a minor component of compost or mulch could be successful. However, there needs to be further research conducted to support the application including exploration of the effect of different environmental conditions on the breakdown of the treatment chemicals plus solvents and dyes and determining the maximum proportion of H2F treated timber in mulch. Potential users of the resource also need to be identified prior to making the submission which will require evaluation of the cost and availability of the H2F treated timber compared with other potential sources of mulch material and other issues, such as the potential for marketing problems.

While the second EOW code allows all types of chemically treated solid timber to be used to make engineered wood products, it is likely that the first target will be H2F treated timber as the use of envelope treatment results in only a small volume of the timber containing the chemical treatment as the treatment penetrates to 2mm or 5mm depending on the chemical used. For two standard framing timber sizes, the greatest volume of treated wood would be 39% (70x35mm timber with 5mm treatment penetration) and the least would be 13% (90x45mm with 2mm treatment penetration). Hann et al. (2010) identified costs of cleaning (removing undesirable material) and

[14] https://environment.des.qld.gov.au/__data/assets/pdf_file/0014/103109/wr-eowc-approved-acq-treated-timber.pdf

[15] https://environment.des.qld.gov.au/__data/assets/pdf_file/0022/90256/wr-eowc-approved-chemically-treated-solid-timber.pdf

[16] https://www.timbertradernews.com/wp-content/uploads/2021/09/2021-TimberTreatmentBooklet.pdf

transporting waste wood to be key barriers to its use in particle board manufacture. Borg in NSW currently recycle H2F treated offcuts collected from frame and truss manufacturers into particle board, which may reflect the higher cost to dispose of this material in landfill in NSW compared with in Queensland.

Use of treated wood waste for energy production is common in Europe and has been raised as a potential use of treated wood in Australia. In Europe, combustion of treated wood waste is governed by the Waste Incineration Directive, which sets limits for air pollutants, including dust, nitrogen oxides, sulphur dioxide, hydrogen chloride, hydrogen fluoride, heavy metals and dioxins and furans. Significant quantities of dioxins and furans can be produced through the combustion of wood treated with tebuconazole or permethrin, particularly when copper preservatives are also present (Tame et al., 2007). Barriers to use of treated wood waste for energy in Australia include: public opinion, uncertainty about the type and degree of treatment or coating on waste wood feedstocks, particularly from C&D waste streams, and, variability in supply as quantities of waste are generally governed by the level of economic activity. The Queensland Energy from Waste Policy[17] notes that the use of waste as a resource would require development of an appropriate EOW code. While the policy does not explicitly mention treated wood waste, it notes that environmental impacts of energy from waste activities would be regulated under the relevant environmental protection policies.

7.6.1.1 CCA treated timber waste

As noted in the previous section, an existing Queensland EOW code allows the use of chemically treated solid timber (including CCA treated timber) "to manufacture engineered wood products or dimensioned timber products". Since the 1980s, there has been a considerable amount of research into potential ways to reuse waste CCA treated timber, including as a component of particle board, cement-bonded particle board, flake board, wood-plastic composites, and wood-cement composites (Mohajerani et al., 2018). In many cases, the boards and composites made using CCA treated timber had acceptable strength and other properties. However, no evidence was found during the research for this report suggesting that CCA treated timber was being used in Queensland to make these products. The likely reason is that users of the boards and composites and those disposing of or recycling the waste, would need to be made aware of the potential for release of CCA treated wood particles when boards or composites were cut and for leaching of arsenic, in particular, during service or disposal.

A recent report into suitable feedstocks for composting in Queensland (Wilkinson et al., 2019), while recognising that the Australian standard for composts, soil conditioners and mulches (AS 4454-2012) allows low proportions of arsenic, chromium and copper to be present, recommended exclusion of all treated wood waste. The current Queensland End Of Waste code for biosolids (EOW code ESR/2018/4548), however, allows use of waste biosolids with low levels of copper and chromium and arsenic as a component of compost and mulch (Table 6) suggesting that an EOW code could be developed that would allow CCA treated timber to be used as a small component of compost or mulch manufacture in Queensland. Further research would be required to determine the maximum allowable proportion of CCA waste. As an indication, Townsend et al. (2003) found that adding 6% CCA treated timber to wood mulch resulted in arsenic, chromium and copper concentrations of 84, 114 and 66 mg/kg, respectively, which exceeds Australian standard AS 4454-2012 limits for arsenic

[17] https://www.qld.gov.au/__data/assets/pdf_file/0020/118433/energy-from-waste-policy.pdf

and chromium in compost and mulch. The biosolids EOW code recognises that the risk to human health from contaminants in compost and mulch is dependent on where they are applied and as such defines three grades of biosolids differing in their restrictions on their use. If these grades, or similar, were adopted for compost and mulch, it would potentially allow greater quantities of CCA treated wood to be used as a component of mulch.

Table 6. Copper, Chromium and Arsenic limits (dry mass mg/kg) for use of waste biosolids as a resource in Queensland (EOW code ESR/2018/4548). Note that limits and restrictions also apply to other contaminants not listed below. See the EOW code documentation for full details.

Contaminant	Grade A	Grade B	Grade C
Arsenic	20	20	20
Chromium (total)	100	250	500
Copper	150	375	2000
Allowable uses	Home lawns and garden Public contact sites Urban Landscaping Agriculture Forestry Soil and site rehabilitation	Public contact sites Urban Landscaping Agriculture Forestry Soil and site rehabilitation	Agriculture Forestry Soil and site rehabilitation

The majority of the copper, chromium and arsenic component in CCA treated timber can be removed prior to reuse through treatment with Oxalic acid followed by bioleaching using *Bacillus licheniformis* (remediation) (Mohajerani et al., 2018), however, this increases the costs of CCA timber waste reuse and also requires a means of disposing of the metals extracted from the treated timber. Similarly, if CCA treated timber waste is burnt to generate electricity or to produce biofuels via pyrolysis, metals in exhaust gases and ash need to be captured and disposed of. An approach to covering the additional costs associated with the toxic metals from treating or burning CCA timber waste, could be to charge to accept the waste but at a lower rate than the current disposal costs.

8 Potential funding opportunities

8.1 Australia wide funding opportunities

Forest and Wood Products Australia (FWPA)

The FWPA are the major funding body for forest research in Australia. Research related to the knowledge gaps identified in this report fits within the funding guidelines of the FWPA.

https://www.fwpa.com.au/

Australian Renewable Energy Agency (ARENA)

ARENA has a number of funding options available to facilitate research and development related to renewable energy.

https://arena.gov.au/funding/

Clean Energy Finance Corporation (CEFC)

The CEFC can assist businesses to reduce their emissions. In the current study, this includes use of biomass for bioenergy and diversion of waste from landfill.

https://www.cefc.com.au/

8.2 Queensland funding opportunities

Regional Futures – Collaborative Projects

Grants up to $200k matched 1:1 by applicant. Applicant must be based outside Brisbane city council boundary. One of the target industry areas is biofutures. Applications open Sept. 2022.

https://advance.qld.gov.au/industry/regional-futures-collaborative-projects

Regional Forestry Hubs

Queensland regional forestry hubs may in future provide funding for further research related to forest and wood biomass recovery.

https://www.qldforestryhubs.com.au/

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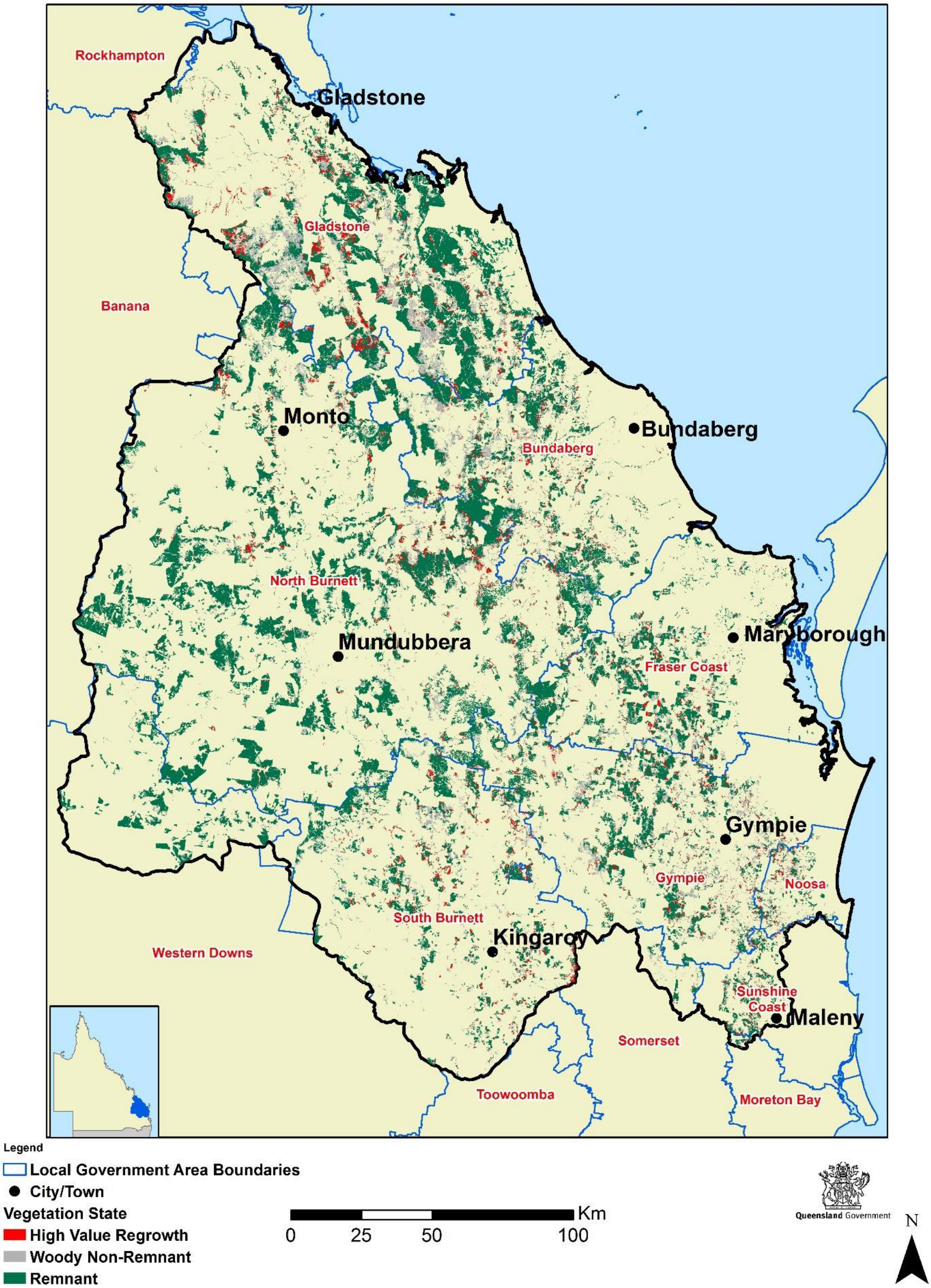
Appendix 1.1 Potentially productive private native forest extent in the south-east Queensland region. (Lewis et al., 2020)

Forests are categorised as remnant vegetation, high value regrowth vegetation or woody non-remnant vegetation (regrowth that unregulated) based on Queensland mapping layers.

Appendix 1.2 Potentially productive private native forest extent in the Wide Bay-Burnett region of Queensland.(Lewis et al., 2020)

Forests are categorised as remnant vegetation, high value regrowth vegetation or woody non-remnant vegetation (regrowth that unregulated) based on Queensland mapping layers.

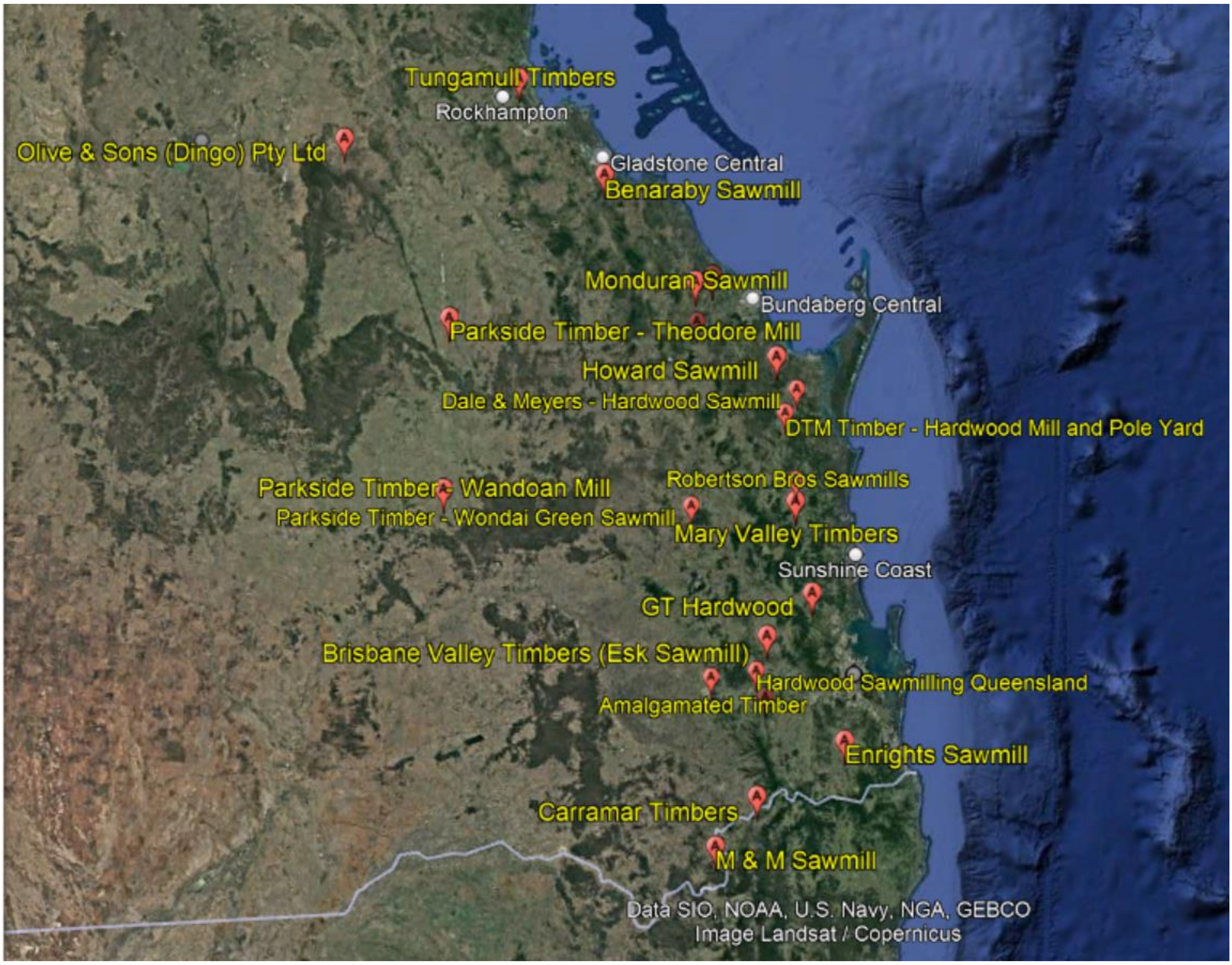


Appendix 1.3 Potentially productive private native forest extent in the western region of Queensland (Fitzroy and Darling Downs).(Lewis et al., 2020)

Forests are categorised as remnant vegetation, high value regrowth vegetation or woody non-remnant vegetation (regrowth that unregulated) based on Queensland mapping layers.

Appendix 2.1 Hancock Queensland plantation locations and extent.

Appendix 3.1 Native hardwood sawmill locations in the study area



Appendix 3.2 Softwood sawmill locations in the study area

Southern pine sawmills are marked with a red icon. Araucaria sawmills are marked with a white icon.