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Tasmanian Government
Department of State Growth

Forest Residues Solutions Study

Stage 2 – Detailed Options Analysis

Final Report

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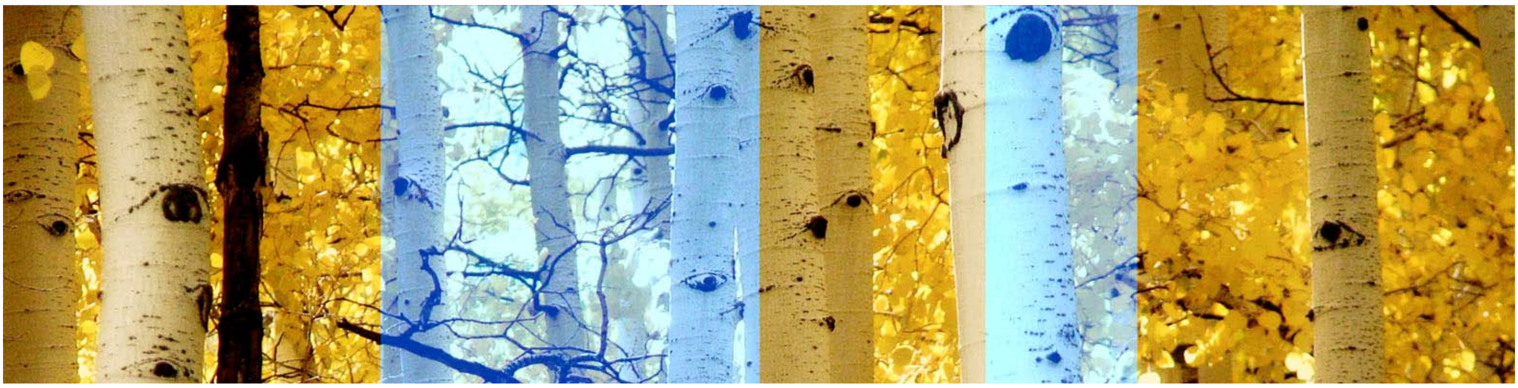

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PREFACE

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EXECUTIVE SUMMARY

This study is intended to support the Tasmanian Department of State Growth (DSG) in the development of a strategy to better utilise forest and timber processing residues generated in Tasmania as well as providing input to long-term forest policy development and planning.

Residues is a generic term for material generated through the harvesting and processing of forests. It excludes sawlogs, veneer logs or peeler billets. For this study it is considered that forest residues could arise from public and private native forests and plantations. An analysis of residue availability indicates approximately 6-8 million tonnes/year is potentially available state-wide. Part of these residue flows are already utilised by other wood processing supply chains, most notably in being exported as woodchips for pulp and paper production in North Asian countries.

The investigation has been completed in two stages. Stage 1 considered 23 potential residue processing options and identified six options that warrant further investigation as part of Stage 2. The six options are: plywood, glulam/cross laminated timber, stand-alone bioenergy (for power production), cogeneration (for heat and power generation), hydrocarbon biofuel (as a drop in liquid transport fuel), and wood pellets.

Key elements of the investigation include: an in-depth assessment of end markets, consideration of where Tasmania may have a competitive advantage, an assessment of supply chains and pathways to market, feedstock availability, and an assessment of option viability.

The following sections provide an overview of the findings for each option.

Plywood

Plywood is a major timber product with global consumption of around 100 million m^3 annually. Plywood can be manufactured for a range of end uses. It is used extensively by the construction industry for concrete formwork and layup but is also manufactured for a range of interior appearance and non-structural applications. While plywood was considered to be a product in general decline around the turn of the century as it lost market share to softwood panels, demand in the Asia Pacific region has continued to grow, particularly in China which is the world's largest producer and exporter of plywood.

Historically most of the plywood produced in the Asia Pacific region used large diameter tropical hardwood logs as a feedstock. Major plywood producer countries such as Malaysia and Indonesia sourced these logs from native forests. As the supply of tropical hardwood logs has declined, and low cost labour has become increasingly accessible in China and more recently Vietnam, a plywood industry based on small diameter hardwood plantation logs has emerged. This high labour, low capital model produces veneer sheets which are then sold to plymill factories who complete the plywood layup and cutting process. Chinese and Vietnamese plywood manufacturers use both domestically grown hardwood plantation logs and imported supplies. These logs are significantly smaller than traditional supplies and require different equipment for the peeling processes.

The Chinese plywood sector utilises significant volumes of eucalypt plantation logs, including plantation grown *Eucalyptus nitens* logs from Tasmania. Low production costs allow this supply chain to be competitive despite the cost of importing logs from countries such as Australia. The competitiveness of this supply chain can be demonstrated through the export log price for hardwood logs which are currently comparable to prices paid for logs delivered to an Australian export chip mill.

With a domestic industry based primarily on softwood plywood production, Australia is a net importer of structural and non-structural plywood. Imports comprise a wide range of plywood products, reflecting the variety of potential end uses in the Australian market. With population growth underpinning demand for housing, especially intensive residential developments, Australian demand for plywood is expected to grow over the medium term.

Plywood manufacturing in Australia is established using a more traditional arrangement, with the process being capital intensive and requiring significantly lower labour inputs than observed in China or Vietnam. The small volume of hardwood plywood produced in Australia is based on large diameter hardwood logs sourced from native forests. Very little hardwood plantation material has been processed to date by the plywood sector in Australia and the understanding of the performance of plantation hardwoods is limited.

From a residues perspective, the most likely feedstock for a plywood mill in Tasmania would be sourced from hardwood plantations, most have which have been managed to produce pulpwood (i.e unpruned and unthinned). Peeling trials in Australia indicate the grade outturn of plywood from plantation grown *E. nitens* logs sourced from pulpwood plantations would be predominantly lower quality veneer more suited to plywood core material, rather than the higher value face veneer sheets. These properties could potentially be improved over time through targeted breeding programmes and optimizing the peeling and drying process.

A poor grade outturn makes the business case for domestic plywood production from plantations managed for pulpwood more challenging. While the cost to produce this type of plywood in Tasmania is higher than other international producers, its use by offshore processors suggests it has some future, potentially in veneer form, where it can be combined with a higher quality face and back veneer sheet to produce a more valuable plywood product. Regional veneer markets are expanding rapidly, particularly in countries such as China and India which are importing large volumes of core veneer material.

Glulam/Cross Laminated Timber

Glulam and cross laminated timber (CLT) are used in high strength beam, column and wall construction applications as an alternative to steel and concrete. Glulam has visual attractions as well as functional values, while CLT also provides differing functional uses including enhanced sound acoustics and thermal properties where it is used as wall, ceiling and floor substrates.

Glulam is a well-known product with global consumption of some five million m^3/year. CLT demand has grown significantly over the past decade to around 700,000 m^3/year, particularly in European markets where it is a widely accepted method of construction. This growth has occurred through the revision of various building design and construction codes. Key CLT benefits arise through precision building design and then significant reductions in construction time and labour.

CLT use in Australia to date is limited to two multi-storey buildings completed in Melbourne. The CLT for these projects was sourced from European producers. In contrast, the Christchurch earthquake reconstruction has underpinned the development of a CLT manufacturer Xlam based in New Zealand. Hardwood and softwood glulam is already produced in Australia in small quantities. Both facilities use low quality timber as a feedstock with the glulam plant part of a larger sawmilling operation. Hardwood glulam is produced in Victoria using timber from native ash eucalypt species similar to those found in Tasmania.

The potential for CLT is significant, given its end uses include detached housing, multi-storey residential construction and non-residential construction. With the continued trend towards multi-storey housing in Australia, CLT has the potential to capture part of this market from the steel and concrete alternatives. Depending on the potential for CLT to penetrate this market, CLT demand in Australia could increase significantly.

Construction cost assessments using glulam and CLT indicate both products can be price competitive with steel and concrete construction for a range of residential and non-residential building types. While glulam use is well understood globally, it occupies a niche market in Australia that would benefit from greater promotion to stimulate further demand. CLT requires a reconsideration of building design and construction approaches which underpins CLT's key core attributes – reduced construction costs and timeframes. The cost competitiveness of CLT is expected to improve over time as scale increases and the manufacturing process becomes more efficient.

CLT and glulam processing scale is relatively flexible and can be of relatively low capital cost. However, to date CLT has been a softwood product, capturing benefits in aligning lighter timber weight with increasing load bearing capacity in the finished product. A hardwood CLT product arising from Tasmanian hardwood sawn timber would require extensive R&D to confirm the feasibility of production and seek to capitalise on differing strength and weight characteristics. In addition, revisions to the construction code and greater familiarity with the use of CLT and glulam for construction would be key components to stimulating greater consumption and realizing the potential to gain further efficiencies through the supply chain.

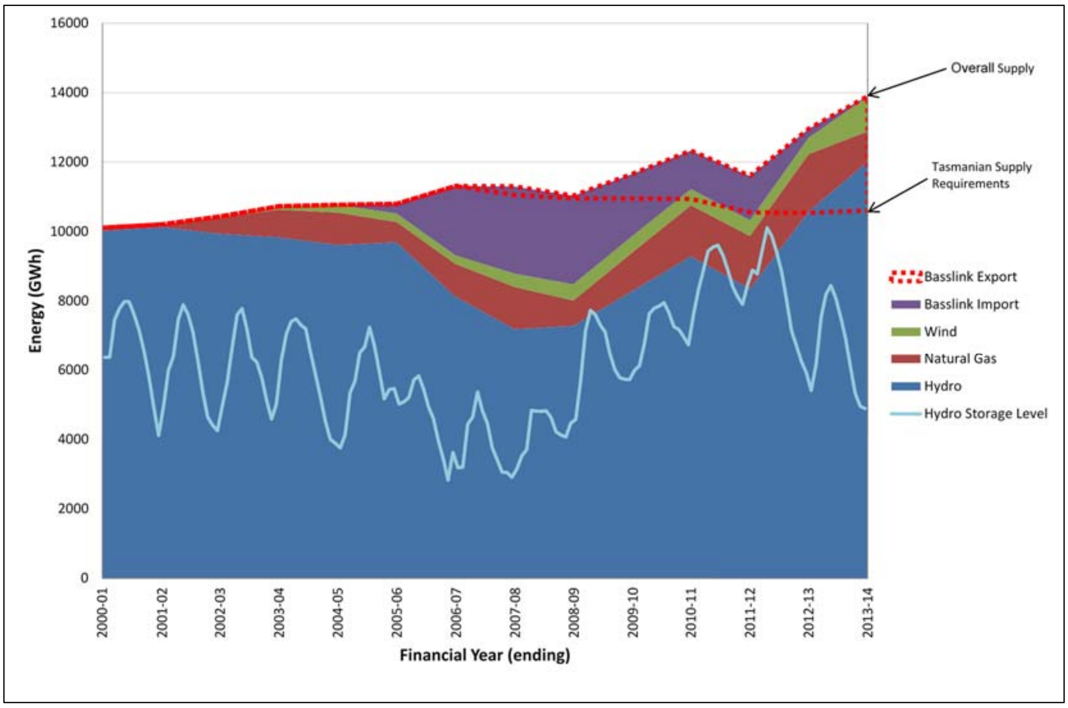
Stand-Alone Bioenergy for Power Generation

The Tasmanian electricity market is mature with a number of different generation options available. Hydroelectric power is the largest accounting for 76% of Tasmania's installed generation capacity. In recent years, Tasmania has been a net exporter of electricity through the Basslink cable to mainland Australia via the National Electricity Market.

Electricity demand in Tasmania is expected to remain flat with energy intensive industries at a mature rather than expansionary stage of development. Energy efficiency initiatives and developments in other renewable technologies such as rooftop solar are also impacting on demand for electricity from the grid.

The Renewable Energy Target (RET) is a longstanding federal government program that supports and promotes renewable energy via incentives for the generation of electricity from eligible renewable sources Electricity from wood currently supplies only around 1% of the eligible generation under the RET, and has not changed significantly over the past ten years.

Tasmanian Electricity Supply by Source



Electricity generation from biomass can use a number of different technology pathways, all of which are mature with known costs. This suggests any major technology enhancements beyond existing performance are likely to be limited. Many technologies have the capacity to process a wide range of biomass types, including woody biomass.

Electricity from woody biomass is almost always produced via combustion technology, as such its environmental compliance is well understood and bioenergy plants are capable of routinely meeting EPA emission requirements.

The cost to produce electricity from biomass currently exceeds the wholesale electricity price even when: Large-scale Generation Certificates are taken into account; the scale of the biomass facility is maximised (to reduce the unit cost of production); and the cost of feedstock is effectively zero. Without increases in electricity prices or explicit government support, bioenergy generated electricity is only competitive to particular electricity consumers or circumstances.

The most prospective development for stand-alone bioenergy in Tasmania is as a cost effective alternative to enhancement of the electricity transmission or distribution infrastructure in the future. No such opportunities were identified during the study.

Cogeneration

Stand-alone Combined production of Heat and Power (CHP) plants are common in some European countries due to a combination of policy support, subsidies and a good alignment with existing district infrastructure for the distribution of both electricity and heat. Conversely the nature of the infrastructure arrangements for heat and power in Australia means large scale cogeneration opportunities are largely limited to the industrial and commercial sectors.

Demand for cogeneration is very site specific and requires the alignment of demand for electricity and heat with sufficient quantities of feedstock to meet the capacity of the system.

Cogeneration has relatively modest fibre requirements. A 15 megawatt (MW) facility, which is large by Australian standards, would require residue feedstock of approximately 54,000 green tonnes/year to run at full capacity. Existing cogeneration facilities typically rely on a feedstock located in close proximity to the site or have access to low cost residues (such as sawdust) with limited alternative commercial markets. Trends from existing facilities in Australia and internationally indicate a preference for processing residues rather than biomass sourced directly from forests.

Key sectors of the Tasmanian economy that utilise heat and could be considered prospects for cogeneration include the wood processing sector, the dairy sector, vegetable processors and the minerals processing sector. The commercial success of cogeneration depends on at least five separate variables:

- The scale and variability of energy needed;
- Existing cost for heat and electricity;
- Cost to secure biomass;
- Equipment requirements; and
- Meeting a required return on the capital invested.

Each variable has a wide input range and the interaction between them means each cogeneration opportunity must be considered on its own merits.

Provided the heat requirements are compatible and the key criteria associated with these variables are met, it may be possible that heat and electricity produced at one site could be distributed to a number of industrial users. This allows for further consideration of the benefits associated with economies of scale and maximising utilisation, both key drivers of the capacity to pay for biomass.

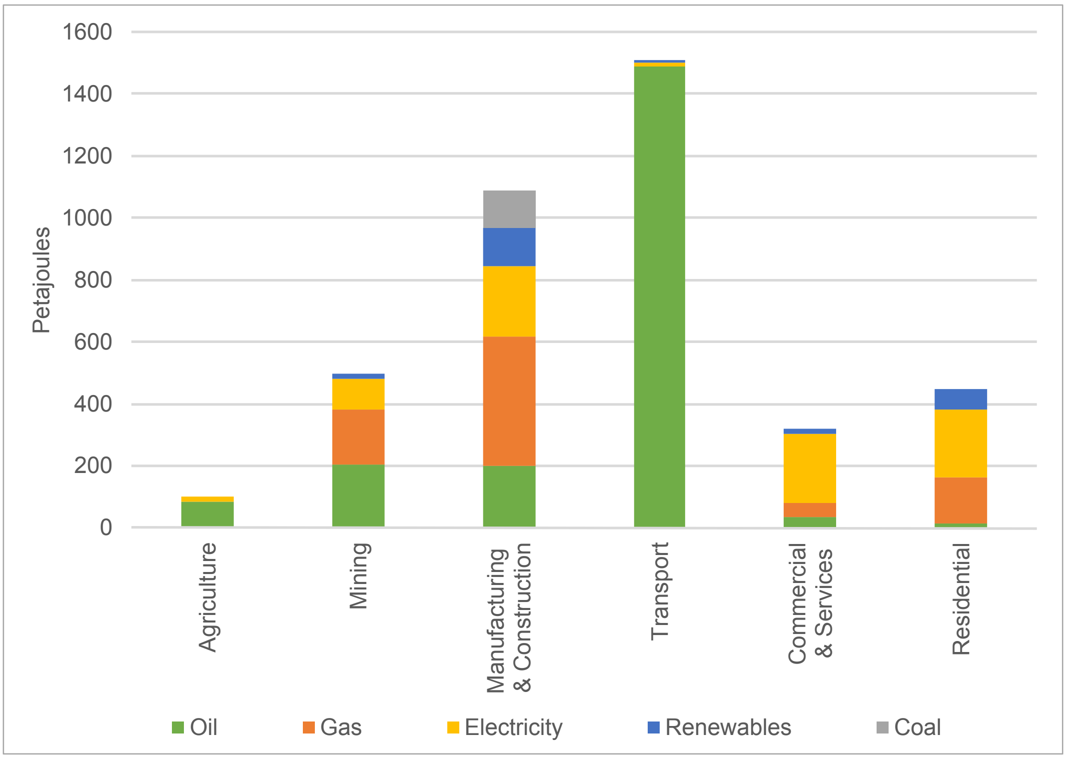
Hydrocarbon Biofuels as a “Drop in” Transport Fuel

Liquid transport fuels represent the greatest source of energy demand in Australia. Tasmania’s share of the total national petroleum demand of 55 billion litres is 1.5% or 850 million litres/year. This demand comprises 43% petrol, 44% diesel with the remaining 13% a combination of LPG, aviation fuel and other minor fuels. As Tasmania has no refining capacity all fuels are delivered in their final form.

Fuel prices are volatile and follow international price developments. Australian retail petrol prices are lower than most other OECD nations largely due to lower levels of taxation. Retail prices in Tasmania tend to be higher than other Australian states. The price differential is due to the same factors which influence regional locations compared to metropolitan centres. These include: lower levels of local competition; lower volumes of fuel sales; lower convenience store sales as well as distance and location factors.

“Drop in” hydrocarbon biofuels can blend in or replace fossil fuels, representing no discernible change for consumers. Their potential market in Tasmania is some twenty times that of ethanol blended biofuel. A large scale drop in hydrocarbon development could potentially utilise most or all of the state’s woody residues. This has the potential to provide the Tasmanian economy with a locally produced renewable liquid fuel option based on forest residues.

Profile of Current Energy Usage in Australia



The development of hydrocarbon biofuels is being driven by policies aiming at reducing greenhouse gas emissions as well as decreasing reliance on imported fossil fuels. Sixty-four countries globally have government policies in place with targets or mandates for renewable transport fuels.

The technologies being developed to produce hydrocarbon biofuels are generally some years away from full commercial deployment. Many of these technologies are at near commercial status in the US and Europe as a result of several billion dollars of government and private investment. Hydrocarbon biofuels can be made from both hardwoods and softwoods via a number of processes, none of which require the addition of hazardous chemicals.

Meeting fuel standards does not appear to represent a material barrier to market, but the declining status of Australia’s current refining capacity is a considerable risk factor. This could be addressed by building a smaller scale bio-refinery in Tasmania to establish a biofuel industry.

The current cost to produce drop in hydrocarbons exceeds comparable fossil fuel prices. These production costs are expected to decrease over time as efficiencies are realised through technological development as has occurred in the wind and solar energy sectors. A key benefit of a drop in hydrocarbon facility is it would have the capacity to utilise the existing fuel distribution network, unlike blended biofuels which require their own infrastructure.

The likely pathway to development is utilisation of a licensed technology, coupled with a major capital investment in state based refinery capacity. Aligning with existing fuel distributors would be an important factor in the latter stage of the development pathway.

Widespread utilisation of biofuels would have a material impact on the greenhouse gas emissions associated with the transport fuel supply chain. Life-cycle emissions from renewable fuels have been estimated to be 74% lower compared to conventional oil-based fuels.

Wood Pellets

Renewable energy policies have driven the development of global wood pellet consumption patterns. These policies mostly relate to heat and electricity generation with wood pellets replacing alternative energy sources as part of a carbon emissions reduction framework. With many policies being nationally based, the pellet trade has responded according to policy targets and the potential to source supply from domestic markets. While the policy modalities can vary by jurisdiction, infrastructure arrangements and the location of pellet consumers all influence the demand and form of the global pellet trade.

The global trade of wood pellets was estimated to be ~28 million tonnes in 2014, with 70% of this trade being sourced in Europe. To date most wood pellets have been supplied domestically from a number of European states. However, with European demand expected to continue growing, pellet sourcing is likely to be increasingly met from suppliers outside of Europe. Wood pellet producers along the east coast of Canada and the US have a well-established supply chain into the European market. Any further increase in European demand is likely to see a continued expansion of the north Atlantic pellet trade. Distance to market is a key barrier to Australia being a competitive supplier to the European market.

Within the Asia Pacific region, policy developments have resulted in a marked increase in the import of pellets into Japan and South Korea. Current policy settings are expected to result in further growth in the pellet trade through to 2020 for both countries, but South Korea in particular as it relies heavily on pellet imports. These countries represent the most prospective markets for Australian sourced pellets, given proximity in terms of transport distance and costs, and traditional wood product trading relationships.

Current global trading is primarily based on white pellets, where wood is pulverised and compacted into a form suitable for transportation. An emerging technology is the development of black pellets which are produced through thermal treatment of biomass to remove additional moisture and increase energy density. While black pellets offer significant benefits in terms of transportation efficiencies due to pellet energy concentration and potentially avoid the blending limits associated with white pellets, little commercial development of black pellet manufacturing has occurred to date.

Japanese pellet imports are dominated by Canadian supply, while South Korea has sourced pellets from the entire Asia Pacific region, with Vietnam and China key suppliers. Given white pellet feedstock can range from a variety of tree species along with non-woody supplies such as palm oil bunches and rice residues, increasing import demand from Japan and Korea is likely to be meet from a range of existing and emerging suppliers through the Asia Pacific region.

International pellet pricing to date has been relatively volatile, partly reflecting the emerging development of market norms and diversity of potential suppliers. A key price indicator has been the delivered price into Korean and Japanese ports (cost insurance and freight (CIF)), with prices generally varying in a band from USD150-250/tonne, although the current Korean price is below this range.

Given the relatively low capital costs, and flexibility in feedstocks that meet market requirements, a wide range of new pellet plant developments are under consideration through the Asia Pacific region.

Tasmanian produced pellets have the potential to supply North Asian markets. With pellet plant scale typically ranging from 75,000-150,000 tonnes/year, Tasmania has a number of locations with adequate residue supply to support a pellet mill development.

Current cost estimates for constructing and operating a pellet plant indicates a Tasmanian exporter would be able to compete domestically for fibre (i.e. log purchasing) when CIF prices approach or exceed USD200/tonne CIF to Japan or Korea, given an exchange rate of around AUD0.75:USD. However, as prices move toward or below USD150/tonne, the supply chain would not be able to compete to purchase logs.

Large scale pellet manufacturing in Australia represents product development outside of traditional wood products markets such as pulp and paper, timber or panels manufacturing. This diversification can support a business case for developing new pellet mills, particularly where industry participants are able to access both processing residues and logs. A further key component for a viable business case would be establishing a clear route to market, and amelioration of price and volume risk to an acceptable level.

Summary of Stage 2 Options

Given the wide suite of markets, competing products and supply chain arrangements of the six options, the merits of each option have been summarised according to the following criteria:

- Key success factors
- Key challenges
- Barriers to entry
- Potential collaborators
- Potential competitors
- Policy considerations.

The following table provides a summary of the core components of the criterion analysis, and merits and challenges of all options.

Summary of Key Considerations for Stage 2 Options

Criteria	Plywood	CLT/Glulam	Bioenergy	Cogeneration	Drop in Hydrocarbon	Pellets
Key Success Factors	Existing processing knowledge	Existing feedstock of suitably valued timber	Mature technologies and sufficient resource for large scale facility	Ready technologies and residue proximity aligns to potential locations	Seamless integration with existing fuel supply chain infrastructure Potential to use large volume of residues in alignment with Tasmanian fuel needs	Well positioned supplier with existing complementary regional port infrastructure Potential to use large volume of residues
Key Challenges	Quality of plantation grown *E.nitens* Competing in international markets against low cost producers	Market development required for CLT/ glulam, including technical product testing Building standards for use of CLT	Cost competitiveness relative to conventional electricity and other renewables	Achieving sufficient scale Uncertainty over gas prices	Technology proven but not currently commercialised	Cost competitiveness and mitigation of exposure to misalignment between price volatility and production costs
Barriers to Entry	Log quality – unproven in an Australian context Capital costs for a greenfield facility	Building standards and proof of product specifications	As above	Capital cost for biomass CHP plants	Acceptance to the use of native forest residues for energy Capital costs of several billion dollars for greenfields opportunity	Aligning operational scale with alternative feedstock cost structures
Collaborators	Existing producers – further expansion of production base	Property developers, builders and architects in residential and non-residential markets Domestic sawmillers	Major engineering contractors and equipment suppliers	Users of natural gas to generate process heat Wood processors with limited residue markets	International proponents offering licensed technology and existing fuel delivery arrangements	Potential to align with Japanese and Korean trading houses

Criteria	Plywood	CLT/Glulam	Bioenergy	Cogeneration	Drop in Hydrocarbon	Pellets
Competitors	Hardwood pulpwood and log exporters competing for log supply Existing domestic producers and importers	Existing CLT/ glulam producers and importers Steel and concrete producers	Electricity from local wind and hydro and via the Basslink undersea cable	Natural gas and grid electricity producers	Existing fuel suppliers Alternative technologies (e.g. electric or hybrid vehicles)	Alternative wood pellet providers and alternative fibre users
Policy Considerations	Nothing specific identified	Consider the impact associated with a wood first policy	Federal government policy already provides support for renewable electricity generation	No national scheme exists for renewable heat State government has the capacity to facilitate potential pan-sectoral opportunities within Tasmania	Extension of the federal fuel subsidies to include hydrocarbon biofuels	Directly influenced by international renewable energy and carbon pricing policies
Potential Timeframes for Further Developments	Medium term - further trials required to confirm viable peeling/drying techniques and appropriate end uses	Medium term - R&D investigating feasibility of producing hardwood CLT and performance against softwood CLT Short term - hardwood glulam already in the marketplace	Medium to long term - no immediate opportunities identified Dependent on timing, location and scale of upgrades to the Tasmanian electricity network	Short term - uncertainty over future gas prices expected to prompt large, stable users to consider alternatives over next few years	Longer term - commercialisation of technology over next 5-8 years and feasibility and business case studies	Short term - commissioning approval and investment processes for port infrastructure

The more traditional wood products (pellets, plywood, glulam) are generally well understood and feature relatively established technologies. For these options a common key challenge is proving a Tasmanian product would be competitive in end markets in terms of functionality and cost.

For the emerging wood products (in an Australian context) of CLT, drop in hydrocarbon biofuel, bioenergy or cogeneration, the core success factors depend on gaining market acceptance for these products. In these cases, the residue products will be competing directly with non-wood products such as concrete and steel construction, fossil fuels or power generated from hydroelectricity, gas or coal. These non-wood products have well established cost structures and have long operated in the market establishing pricing norms for the respective product. The success of these residue processing options will be influenced by their ability to provide a real alternative to the existing non-wood products.

Prospects for Residue Utilisation in Tasmania

The prospects for each of the six options actually being developed can be assessed by weighing up the following:

- The challenges to securing market acceptance and market access for the finished product;
- The estimated cost of production and in turn the competitiveness of the product given established behaviour of the markets regarding price and quality;
- The status of the product development technologies and product standards developments; and
- The potential for a new processing investment to successfully address a detailed feasibility analysis and related business investment case.

With these perspectives, the six options can be generally assessed to their prospects according to the following rankings:

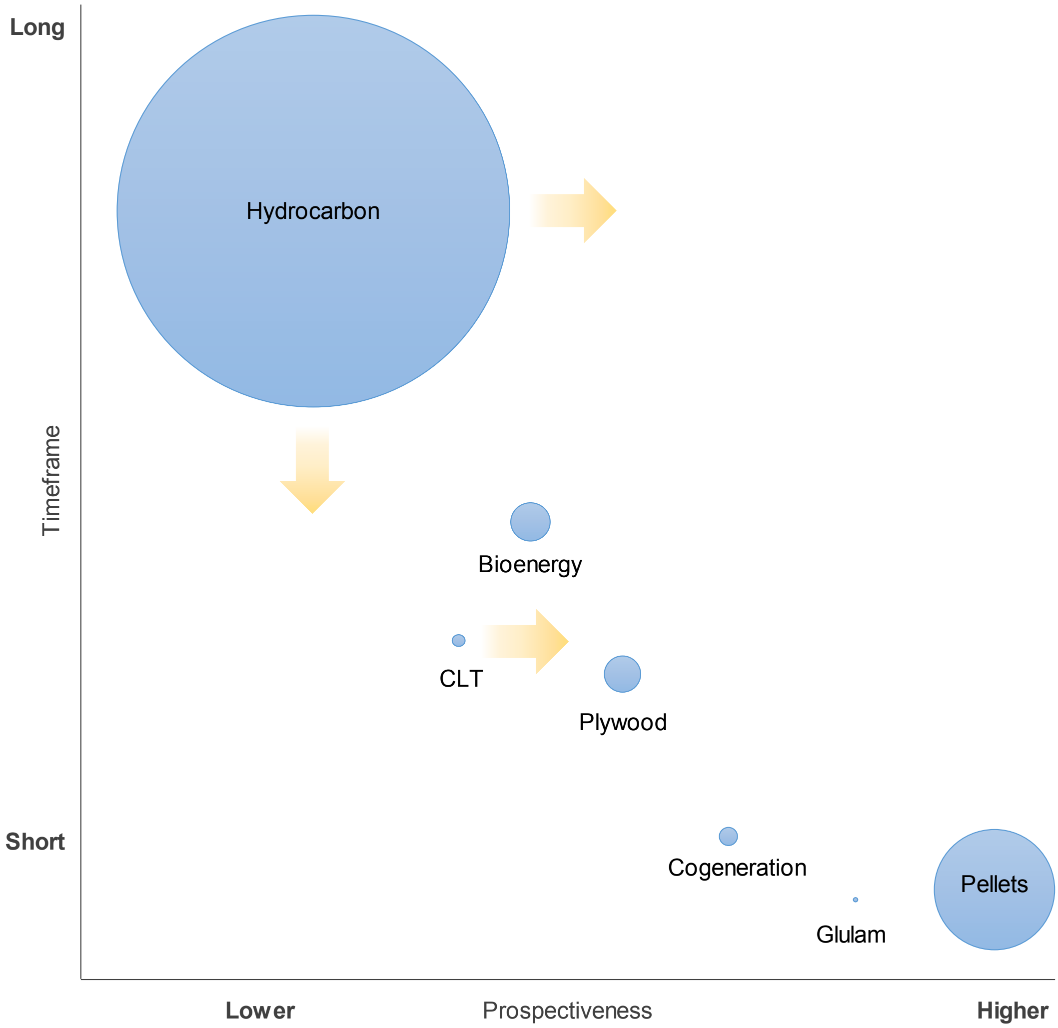
➢ Highest prospects	Wood pellets
	Glulam
➢ Moderate prospects	Cogeneration
	Plywood
	Bioenergy
	CLT
➢ Lowest prospects	Drop in hydrocarbon

Each option has the capacity to utilise differing proportions of the residues available in Tasmania, with drop in hydrocarbon's having the potential to utilise the vast majority of the available supply. Under this scenario, the feedstock available would be sufficient to meet Tasmania's current liquid fuel demand. Alternatively, glulam markets are small and have specialist end use requirements. Therefore, expected glulam processing would utilise a fraction of the available resource.

Furthermore, the timeframes and development pathways for each of these options differ, and will change in the future due to a range of influences including technology commercialization, new product developments and market signals.

The following figure illustrates an indicative positioning of each option according to its potential realisation timeframes, prospectiveness and fibre consumption potential. This figure can assist DSG in assessing the merits of differing interventions as well as completing update assessments of technologies and markets.

Potential Prospects and Timeframes for Each Option



Tasmanian Opportunities

The options reviewed by this study provide a range of opportunities for the Tasmanian economy:

- Diversification of end uses and therefore differing market risks compared to existing markets (i.e. wood pellets), which in turn provide the potential to reallocate supplies between markets depending on the competitive position of Tasmanian supply in respect to market changes;
- Building on existing Tasmanian expertise, and capitalising on the insights of the sector (i.e. plywood, wood pellets);
- Providing alternative power and heat generation sources to the non-forest sector participants (i.e. bioenergy, cogeneration) which can help them mitigate price and supply risks, and well as provide greater direct control over their supply needs;
- Reduce reliance on external suppliers and establish a basis for a broad based Tasmanian energy policy with greater contributions from renewable energy source (i.e. drop in hydrocarbons); and
- Development of new expertise in the state (i.e. CLT, glulam) and reinforcement of the existing processing industry by provision of increased timber product uses.

Enabling Factors

The diversity of the Stage 2 options indicates enabling factors are also of varying source and potential. Enabling factors can be expected to arise from private sector investment and development, as well as actions from international governments, the Australian federal government and the Tasmanian state government.

These factors will include:

- Commercial development of technologies (i.e. in drop in hydrocarbon product commercialisation). These developments are more likely to occur internationally, given the proponents involved and potential applications of such technologies;
- Standards development and code realignments which would assist the prospects for CLT or glulam uses. These could be led by private sector investment or with a degree of support from public sector financing where interests are appropriately aligned;
- Research and development investments from both public and private sector sources, such as exploration of potential black pellets developments or feasibility testing of peeling Tasmanian plantation hardwoods;
- Policy developments relating specifically to renewable energy policies (both internationally and federal governments), carbon emissions policy (internationally and federal government), wood procurement policies relating to construction (state and local governments); and
- Opportunity assessments where multiple contributing factors support a public or private sector investment.

These enabling factors will be controlled and influenced by a range of private sector and public sector stakeholders. The role of government therefore includes maintaining a watching brief on developments in the sector and be able to assess and respond with appropriate government support. Similarly, private sector stakeholders will continue to assess market opportunities, their relative strengths and competitive positions, and capacity to capture an economic gain in expanding their operating arrangements.

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1. INTRODUCTION

1.1 Project Overview

The Department of State Growth (DSG) has engaged URS Australia Pty Ltd (URS), in conjunction with Indufor Asia Pacific (Australia) Pty Ltd and Enecon Pty Ltd (Enecon), to investigate economically viable and environmentally sustainable solutions for the use of forest and timber processing residues generated in Tasmania. The study is intended to support the development of a strategy to implement options to better utilise these residues. It will also provide input to forestry policy and planning required to support the long-term viability of the Tasmanian forest industry.

Residues is a generic term for material generated through the harvesting and processing of forests, excluding sawlogs, veneer logs or peeler billets. The definition includes pulp logs, tree crowns, stumps and offcuts from harvested logs and thinnings sourced from forests. Wood processing residues include woodchips, shavings, sawdust and dockings. For this study, it is considered that forest residues could arise from public and private native forests and plantations.

This investigation has been completed in two stages. Stage 1 considered the widest range of options through an evidence-based analysis to assess the capacity of each option to:

- Provide an environmentally sustainable, commercial down-stream utilisation of residues within Tasmania in the next 5, 15 and 30 years;
- Improve the economic viability and environmental sustainability of timber production in Tasmania; and
- Reduce the volume of residues delivered for export as undifferentiated wood products such as woodchips.

The purpose of the Stage 1 analysis was to identify solutions worthy of more detailed investigation as part of Stage 2.

1.2 Summary of Stage 1 Findings

The residue processing options considered for Stage 1 were classified into nine themes. Within each theme a range of end markets were considered. The options ranged from existing forest product markets to new and emerging technologies that are expected to be commercialised over the 30-year timeframe considered for this study. To evaluate the broadest range of options some products were included even though they may not be ideally suited to the types of residues expected to be available in Tasmania.

A multi criteria analysis (MCA) was used to evaluate each option. A MCA provides a flexible methodology that allows for a meaningful comparison of quantitative and qualitative information. One of the main benefits is that a MCA provides a standardised methodology that is transparent and simple to follow. The key principles adopted for the assessment included: impact on residue volumes, technical feasibility, market potential, economic viability, social and environmental considerations, financing requirements and feasibility timeframes.

The MCA was applied to 23 potential residue utilisation options. Table 1-1 provides a summary of the rating for the options considered to have the best prospects for increasing the utilisation of forest and processing residues in Tasmania.

The preferred feedstock for each of the options is also identified, in descending order of preference. The overall score for each option is noted with ticks (✓) or crosses (✗) over a five year, 15-year and 30-year timeframe.

Table 1-1: Preferred Options for Further Analysis

Process Theme	Product	Preferred Feedstock	Expected Scale (GMT#/yr)	MCA 5 Years	MCA 15 Years	MCA 30 Years
Engineered Wood Products	Plywood	NF, H	100 - 500	2✓	4✓	4✓
	Glulam/CLT	S, P*, H	50 -100	3✓	5✓	5✓
Electricity	Stand-alone power	All	100 - 500	4✓	4✓	4✓
Cogeneration	Industrial	All	100 - 500	3✓	4 ✓	4 ✓
Biofuels	Hydrocarbons	All	> 1 million	Neutral	9✓	9✓
Emerging	Torrefaction	All	> 1 million	3✗	5✓	7✓

Key – P- processing, NF – native forest, S – plantation softwood, H – plantation hardwood, All – any forest and processing residues. P* - not all types of processing residue would be suited to this option,
GMT – green metric tonnes,
✓ - positive prospects, ✗ - negative prospect.

The option to produce kraft pulp also scored favourably with a score of 2✓. However, as the rights to the pulp mill are currently being offered to the market, kraft pulp was not included in the Stage 2 analysis. Vendor due diligence on the acquisition of the rights to construct the mill would be comprehensive, with any sale underpinning the potential viability of the project. We note that a pulp mill would require a significant proportion of the residues available in Tasmania.

Table 1-2 provides a summary of the products not considered for the Stage 2 analysis. For simplicity the summary presents a combination of themes (e.g. panel products) which contain multiple options or a single option (e.g. ethanol) considered as part of a broader theme (e.g. biofuels).

Table 1-2: Options Not Considered for the Stage 2 Analysis

Product Group	Limitations in a Tasmanian Context
Dissolving pulp/ mechanical pulp	Dissolving pulp markets are expected to remain in a state of over-supply for the foreseeable future. New capacity largely brownfields conversion of existing pulpmill facilities Mechanical pulp experiencing structural decline with reduced newsprint demand
Ethanol (as a fuel blend)	The estimated ethanol market in Tasmania is less than 10 million litres/year which is too small for even a single commercial plant
Panel products	Panel consumption in Australia is predominantly based on radiata pine, and the majority of available residue is hardwood A greenfields mill constructed in Tasmania would rely substantially on export markets, which also have a preference for softwood panels
Sawn timber (hardwood pulpwood plantations)	Sawing of small diameter logs is technically feasible and some processors in Tasmania have successfully produced a range of timber products from hardwood plantation material and sold this into domestic markets However, the potential to do so at a large scale is not proven and the lack of markets for low value timber grades is currently a barrier to further development
Wood plastic composites	Demand from major US and China markets are largely met by domestic production. A new plant to satisfy market growth in these regions may only require a few thousand tonnes of wood residues per year and there is no competitive advantage to building such a plant in Tasmania

Product Group	Limitations in a Tasmanian Context
Charcoal/ activated carbon	There are no current industrial-scale markets for charcoal in Tasmania. The Tasmanian market could change if a major user such as a silicon smelter is built, but there are no plans for such a project at this time Charcoal can be further processed to make activated carbon, a product with physical attributes and sufficient value to allow for distribution to international markets. Potential barriers to such a plant in Tasmania are the need for initial product feasibility and market studies, access to technology and marketing networks as well as feedstock costs
Nanotechnology	Favourable long-term outlook but processing is currently more suited as an addition to existing cellulose producing facilities such as a chemical pulp mill

A detailed description of the MCA methodology and in-depth analysis of the results is presented in the Stage 1 report.

1.3 Stage 2 Methodology

Quantitative estimates of residue availability were provided as part of Stage 1. The estimates were prepared by Forestry Tasmania (FT) and Private Forests Tasmania (PFT) taking into consideration residue availability from public and private forests as well as from the processing sector.

Since this data was compiled, a more comprehensive assessment of Tasmania's processing residues has been completed by the University of Tasmania's National Centre for Future Forest Industries (NCFFI). The assessment defined the various types of wood processing and post-processing residues generated across Tasmania. The data was based on a review of the available literature and surveys of timber processors. As this data provides a comprehensive assessment of residue volume, by residue type it has been used to estimate processing residue availability in this report. The report has not been published to date and is identified as (NCFFI unpubl.).

No further forest residue modelling was undertaken for Stage 2, so the residue estimates are based on data provided during Stage 1. Limitations and assumptions associated with the data are noted in the Stage 1 report.

In addition to residue volumes, the Stage 2 analysis involves a more detailed assessment of each preferred option. Key factors considered as part of the assessment include:

- A more in-depth assessment of end markets, including any market niches where Tasmania may have a competitive advantage;
- An assessment of the project proponents, supply chain and potential pathways to market;
- Consideration of feedstock availability; and
- Where possible, high level financial modelling to assess viability and sensitivities. Some options are currently only at a pre-commercial stage, therefore detailed cost data is not available. For these products, costing estimates are based on industry sources.

Some data provided by industry to inform this study was confidential and only a high level summary of the results can be presented. Detailed reporting of all of the cost inputs and product prices is not possible due to commercial sensitivity and protection of confidential information.

The Stage 2 report comprises:

- Forecasts of forest and timber processing residue fibre availability (Section 2);
- Sections 3-8 contain an assessment of each option taking into account:
- The status of current markets and an outlook for future demand;
- An overview of the technology involved and proponents involved in these markets;

- An assessment of environmental and social considerations associated with each option; and
- An outline of a prospective pathway for the further development of each option in Tasmania. This includes a summary of key success factors and prospective barriers to entry.
- Section 9 provides a synthesis of the various options based on the results of the analysis completed in the previous sections.

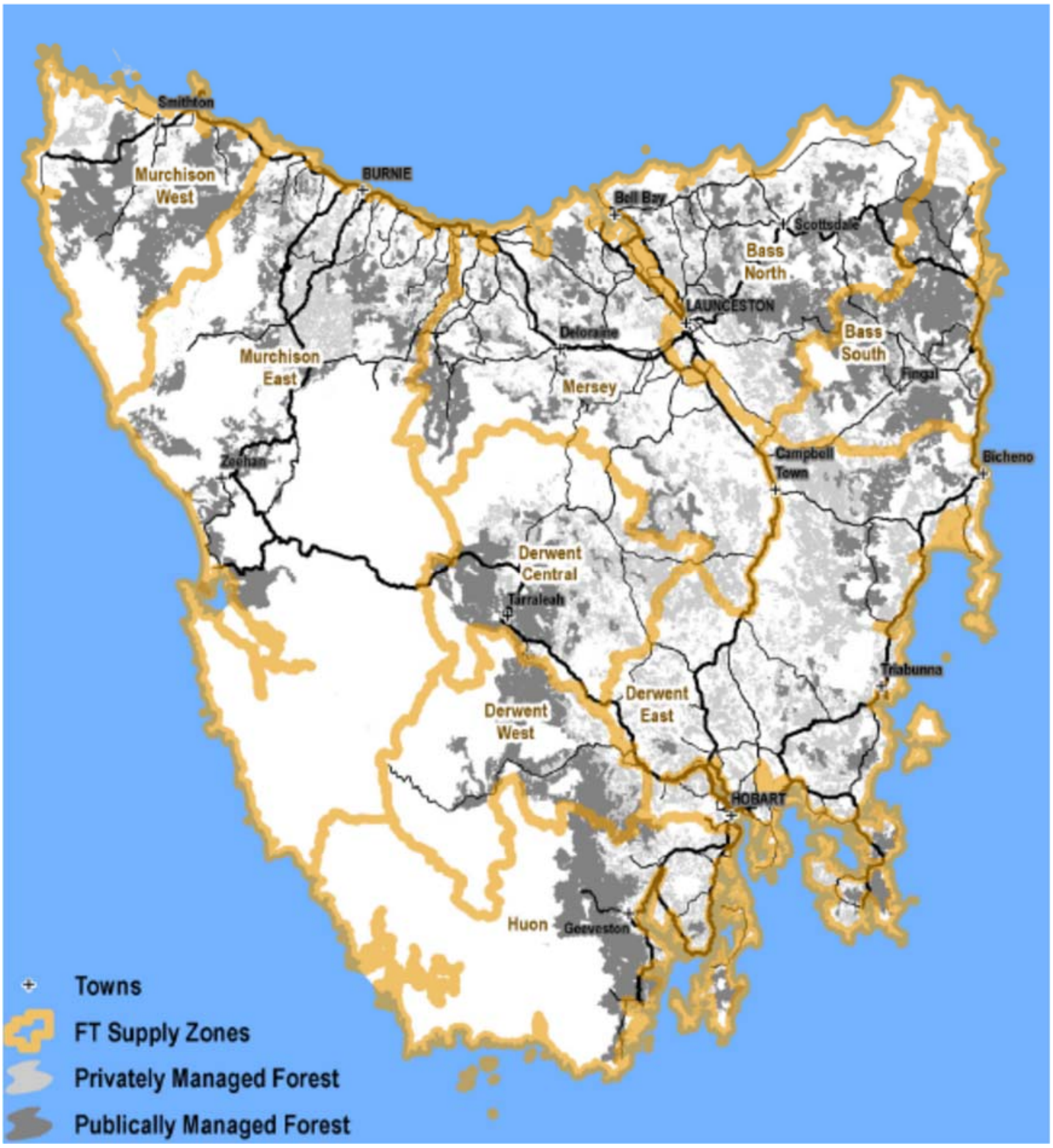
2. FOREST AND TIMBER PROCESSING RESIDUE AVAILABILITY

2.1 Forest Residue Availability

Residue availability from Tasmania's public and private forests as well as from the state's processing sector was modelled by FT and PFT. Residues available from public forests are based on the volume required for FT to meet its contract sawlog and veneer log commitments. As a consequence, residues are generated as an arising from the harvesting process, rather than a driver of the decision to harvest, or a reflection of current market utilisation. The PFT assessment includes supply from privately owned plantations as well as private native forests.

The distribution of forests in Tasmania outside of the national park reserve network is shown in Figure 2-1. The regions in the map relate to FT's supply zones which is the level residue flows are aggregated to.

Figure 2-1 Distribution of Tasmanian Forest Resources



Source: FT

Forest residues are identified in the modelling as either:

- **Pulpwood** - logs of any size not suitable for solid wood processing to a small end diameter of 8 centimetres (cm); or
- **Other Stemwood** - non-merchantable stemwood, including the stump that is usually left in the forest but excludes limbs, foliage and roots.

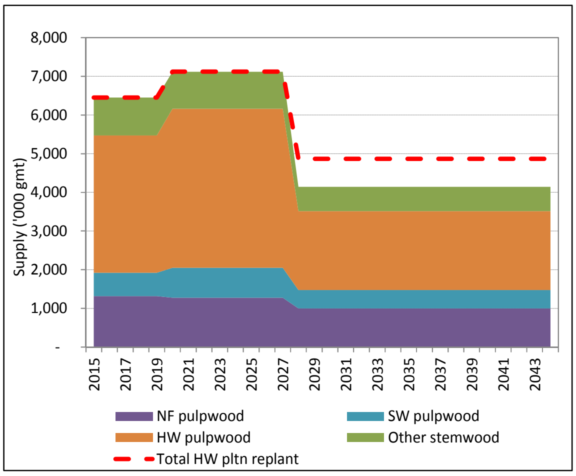
Pulpwood is generally recovered during harvesting operations, where it is commercially feasible to do so. Other Stemwood is not currently recovered from harvesting operations. The viability of collecting Other Stemwood will depend on a combination of the economics of recovery, its suitability for end markets and the environmental impacts associated with its removal from the forest.

With respect to the hardwood plantation estate, two scenarios are presented in the forecast of harvest volumes. One scenario assumes full replanting of harvest areas. The second scenario assumes no company managed plantations are replanted on leased land. The decision to replant will be driven by many factors. However, the assumption of a decrease in hardwood plantation area is not unreasonable as land scarcity during the latter stages of the period of plantation expansion meant some lease costs were higher than what could be justified for a forestry investment. In addition, some plantations have not performed as anticipated and are unlikely to be replanted. Therefore, the partial replanting scenario has been adopted as the base case.

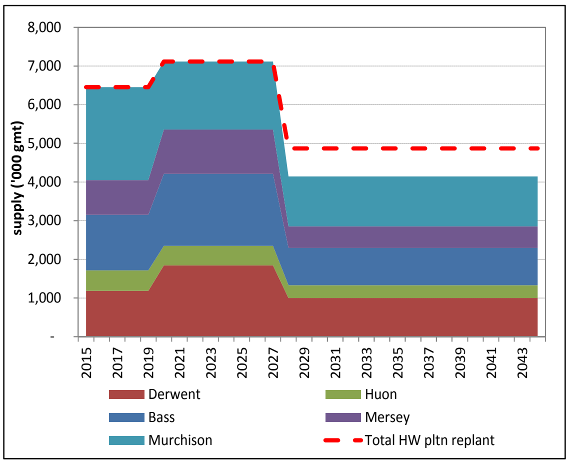
Residue flows are presented at a regional level and aggregated into three lustrums over a 30-year timeframe. These periods correspond with various milestones including FT's contract supply commitments. Figure 2-2 shows projected forest residue flows by residue type (LHS) and sub-region (RHS). The total volume associated with the full replanting scenario is shown as a dashed line.

Figure 2-2: Forecast Forest Residue Availability under Full and Partial Hardwood Plantation Replanting Scenarios

By residue type



By sub-region



Source: FT, PFT

The following points were noted in the Stage 1 report regarding the estimates of residue availability:

- Residue volumes over the first five-year period and 2014/15 in particular is significantly higher than current levels of production. Trade data for 2012/13 indicates the total volume of logs and woodchips exported from Tasmania was slightly more than one million tonnes. Domestic consumption would be less than this volume. Therefore, if residue production remains at similar levels in the short-term, this would lead to an increase in available supply at a later stage;
- Modelled residue availability is at the upper end of our expectations for the capacity of the existing market to absorb additional hardwood chip supply. While this is not material for the purposes of assessing residue availability, the profile would be different if hardwood chip export capacity constraints were to be considered; and
- Other Stemwood accounts for around 950-980,000 tonnes/year over the first 15 years and approximately 630,000 tonnes/year from 2027. Previous operational trials suggest the economic recovery of this material is marginal. While it reasonable to identify Other Stemwood as a potential source of fibre, the capacity to utilise it will need to be determined on a case-by-case basis.

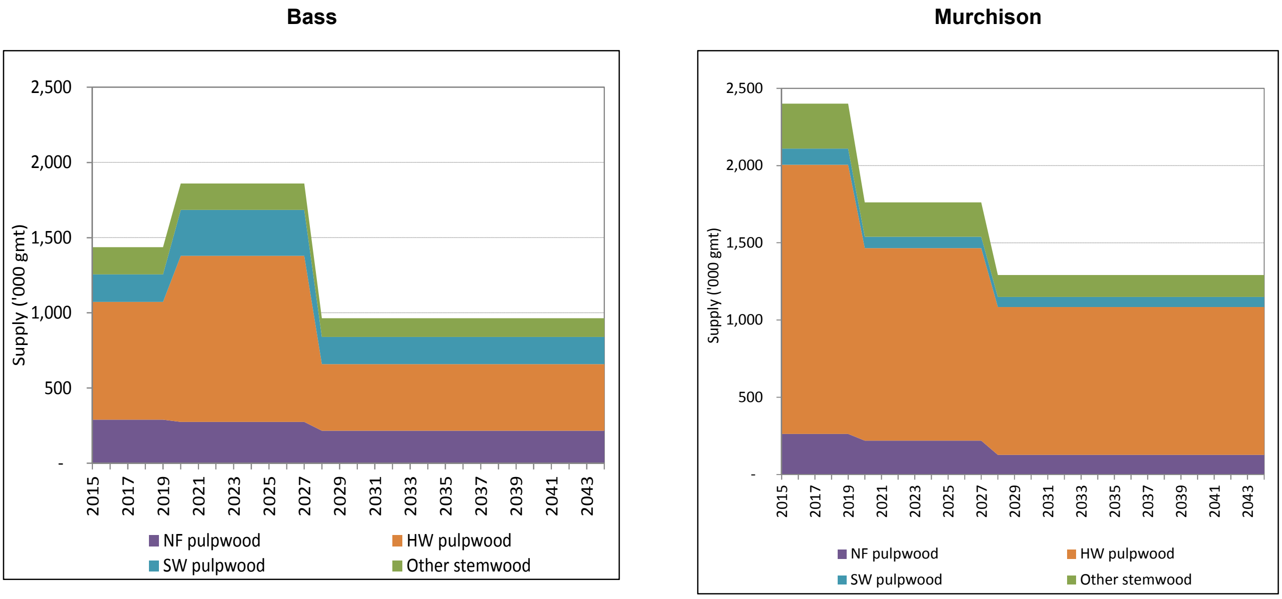
Figure 2-3 shows estimated residue availability for each supply region. The Bass and Murchison regions contain the largest proportion of hardwood plantation. Murchison has the most mature age class profile with nearly 2.5 million tonnes/ year of forest residues currently available. Over 1.5 million tonnes/ year of this volume is expected to arise from the region's extensive hardwood plantation resource.

Residues from native forest harvesting are spread across all regions but account for the greatest proportion of total residue fibre in the Derwent and Huon regions. The Huon region has the smallest volume of residues available at around 0.5 million tonnes/ year.

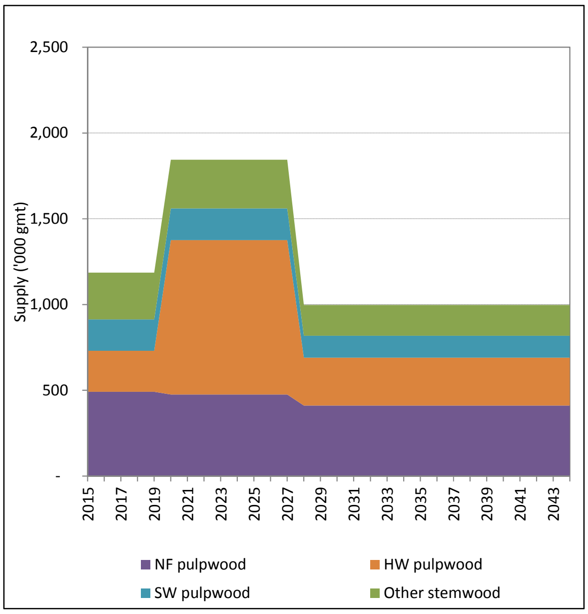
Softwood residues are primarily sourced from the Bass, Derwent and Mersey regions.

Distance to end markets is a key issue for supply from the Huon and Derwent regions, where the cost to harvest and transport logs or chips (more than 200km in some areas) to existing export ports in the north of the state can sometimes exceed the price received for these products.

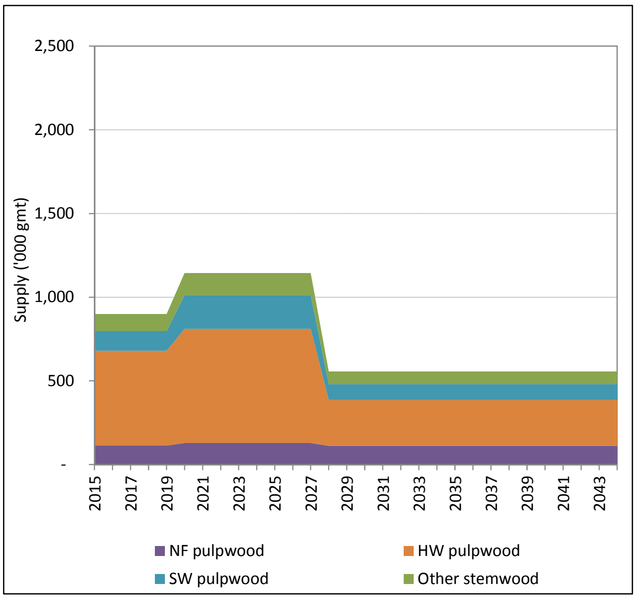
Figure 2-3: Forecast Forest Residue Availability by Region



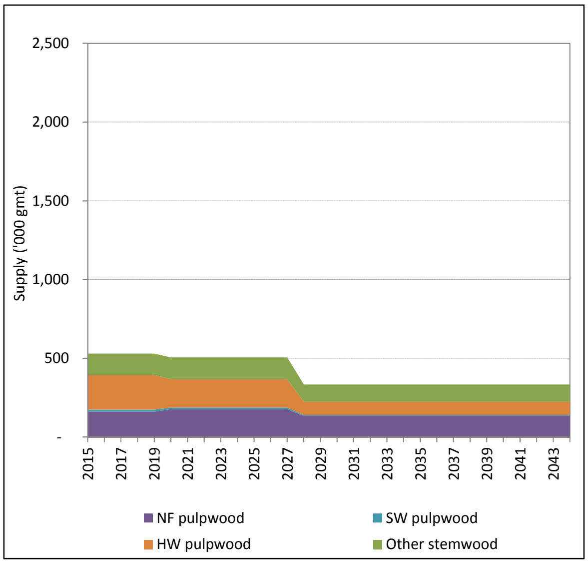
Derwent



Mersey



Huon



Source: FT, PFT

The volume forecasts do not take into account any wood supply commitments which can impact on residue availability as the total modelled supply may not necessarily be available for alternative uses. In terms of committed residue volumes:

- Native forest residues and hardwood plantation residues have traditionally been exported to a range of customers in Japan with supply peaking at around five million tonnes/year. Gunns decision to cease exporting and focus on the development of a pulp mill in Tasmania, along with a high Australian dollar, led to an almost complete cessation of hardwood chip exports from Tasmania. This resulted in Asian customers securing hardwood fibre from other domestic and offshore suppliers. While FT has made some woodchip sales since then, none of the native hardwood pulpwood is committed to a particular end market;
- Forico's acquisition of Gunns plantations and refurbishment of the Hampshire and Long Reach chip mills means the company is likely to focus on supplying hardwood plantation

woodchips to international markets. Provided Australian supply remains competitive, the combined output from the two facilities is in excess of two million tonnes/ year with total woodchip processing capacity in Tasmania of over three million tonnes/ year. This represents a significant proportion of the available plantation hardwood pulpwood fibre. The capacity of the market to absorb this volume has not yet been fully tested. Alternative residue markets would need to demonstrate a comparable or higher capacity to pay than existing wood chip exports; and

- Norske Skog's Boyer pulp mill consumes approximately 550-600,000 tonnes of softwood residues/ year. This accounts for the vast majority of the softwood pulpwood available in the state.

The supply chain for the harvesting and delivery of logs and woodchips is well developed throughout the state. These activities are typically undertaken by independent contractors. As noted previously, there is currently no market for the collection of Other Stemwood. The difficulty associated with handling this material and its low bulk density are key barriers to further utilisation.

2.2 Processing Residues

Wood processing residues arise as logs are progressively transformed into a range of forest products. As a log is cut or peeled the residue generated and can take different forms:

- **Sawmill (green mill)** produces green sawn timber from sawlogs. Residues include: bark, log and board offcuts, woodchips, sawdust and out of specification boards;
- **Sawmill (dry mill)** involves the further processing of kiln dried timber into end products. Residues include: out of specification boards, wood chips, docking and board offcuts, sawdust, planer shavings and sanding dust;
- **Veneer mill** where logs are peeled on a lathe into thin sheets which may be converted to plywood. Residues include: log ends, bark, green veneer as logs are rounded up, peeled cores, waste sliced veneer (green and dried), woodchips, sawdust and sanding dust;
- **Chipmill** – converts logs into export quality woodchips producing bark and out of specification chip material as residues; and
- **Pulpmill** converts softwood logs into paper products. Residues include: bark and wood waste from the chipper.

Processing residue volumes were estimated by NCFFI through a combination of a literature review and interviews with mills to determine the types, characteristics and quantities of wood processing and other residues generated in the state and their various end uses. The interviews are reported to have covered around 90% by volume of Tasmania's primary sawn board and veneer production facilities. A sample of secondary wood processors, and a significant proportion of major residue users were also interviewed. Total processing residue forecasts were extrapolated from the results of this survey (NCFFI unpubl).

Data is presented at a state level with no regional distribution of residue volumes presented. As the report is in draft format, any data presented should be interpreted with caution and may be subject to change.

All processing residues are reported in cubic metre equivalents (compared to tonnes for the forest modelling). The low bulk volume of most processing residue means the mass (measured in tonnes) of this material would be far lower than the cubic metre equivalent.

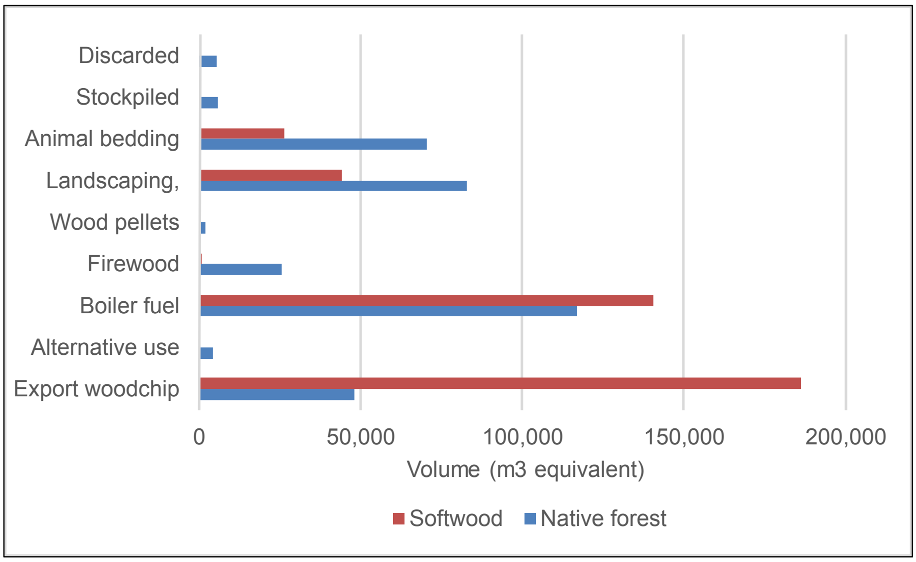
The current utilisation of processing residues in Tasmania is presented in Figure 2-4. It shows total residue volume of around 750,000m^3 equivalent/year on a volumetric basis. Hardwood and softwood processing each account for around 50% of total residue production.

For softwood processing, export wood chips represent nearly 50% of total residue production. Boiler fuel accounts for another 35% with landscaping and animal bedding making up the balance.

Hardwood processing has a more diverse range of end markets reflecting the smaller scale of the sector. Compared to softwood, the export woodchip market represents a much smaller proportion of the overall residue market (13%). Animal bedding and landscaping collectively represent the largest market accounting for 42% of hardwood processing residue volumes. Boiler fuel is the next most common use (32%).

The report notes the economic returns from local residue sales are low with many end markets existing only because residue material is available at very low or no cost. Smaller mills with no chipping capacity or access to export port facilities are being increasingly hampered by bundles of waste-wood which is being stored on site. In some situations the residues are discarded, incurring an additional disposal cost.

Figure 2-4: Current Utilisation of Processing Residues in Tasmania



Source: NCFFI (unpubl)

Processing residues were divided into standardised units based on whether they were green (i.e. produced in the log yard or green mill) or dry (i.e. produced in the dry mill). Sawdust includes fines generated through the chipping process. Waste wood is defined as wing boards, heart, billet cores and other unseasoned offcuts most often produced by mills without a chipper. The composition of processing residues by mill type is shown in Figure 2-5.

It shows woodchips are the most frequently produced residue followed by sawdust, shavings (for softwood) and bark. For chip mills, fines represent the greatest source of residue followed by bark. Collectively these four components account for 97% of all processing residues in the state.

Approximately 75% of all processing residues are produced in a green state, i.e. before being kiln dried and would therefore have a high moisture content.

Figure 2-5: Composition of Processing Residues in Tasmania by Mill Type

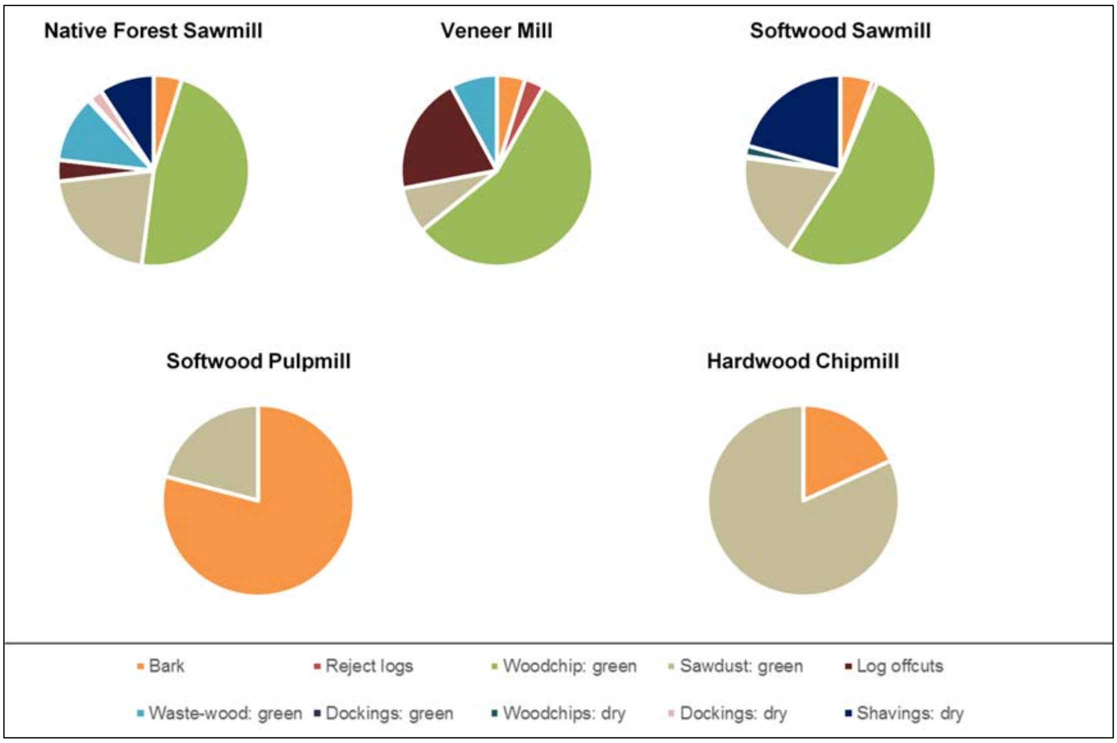
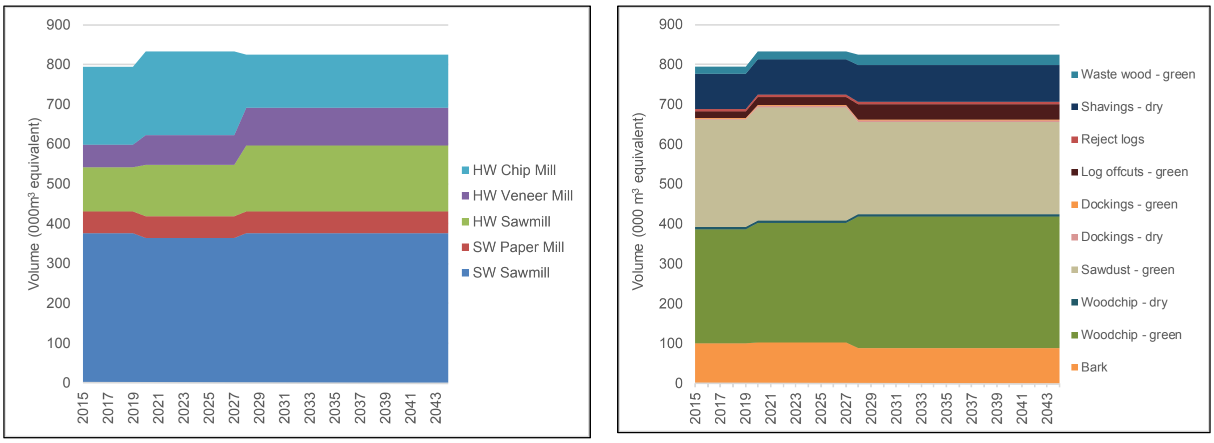


Figure 2-6 shows the projected processing residue availability by mill type (LHS) and residue type (RHS) as determined by NCFFI.

Figure 2-6: Projected Processing Residue Availability



Source: NCFFI (unpubl.)

Key trends and assumptions include:

- Residue volumes are expected to remain relatively constant over time at around 800,000m^3 equivalent/ year. Chip mill residues increase over the short to medium term as existing hardwood plantations are harvested before declining from around 2027. Hardwood sawmill volumes increase around 2027 when long rotation plantation hardwood sawlogs are assumed to be available;
- Softwood and hardwood residues each comprise around 50% of total supply; and
- Wood chips account for the bulk of processing residues (37%) followed by sawdust (34%), bark (13%) and shavings (11%).

2.3 Delivered Residue Costs

The cost to deliver residues to end markets depends on a number of factors. For forests, the key drivers for determining delivered cost are:

- **Forest type** – harvesting in native forests is typically more complex than plantations, especially where operations have a selective (thinning) or retention (seed tree/ habitat) requirement rather than clearfelling;
- **Type of harvesting operation** – thinning operations are generally less productive than clearfelling and therefore have a higher cost;
- **Volume per hectare** - is a function of age and forest productivity. Harvesting operations are generally more productive the greater the harvest volume per hectare;
- **Terrain** – harvesting costs increase as terrain becomes steeper and more broken. As harvesting operations in Tasmania are mostly mechanized, harvesting costs can increase substantially when slopes exceed 22 degrees (the limit for ground based machinery) and specialised cable hauling equipment is required; and
- **Distance to end markets** – haulage costs are linearly correlated with distance. Therefore as distance to end markets increases, haulage costs increase at a uniform rate.

Forest harvesting costs are typically exponential on a unit cost ($/tonne) basis. Very low volumes incur a substantial cost as fixed costs are spread over a small volume and machine productivity is generally low. Costs decrease rapidly as volume increases until it reaches a point where the operation approaches maximum capacity.

For processing residues, the delivered cost may potentially be zero if residue processing is located within the mill gate or sold on a zero cost basis. Alternatively it may incur a transport charge for delivery to the end user.

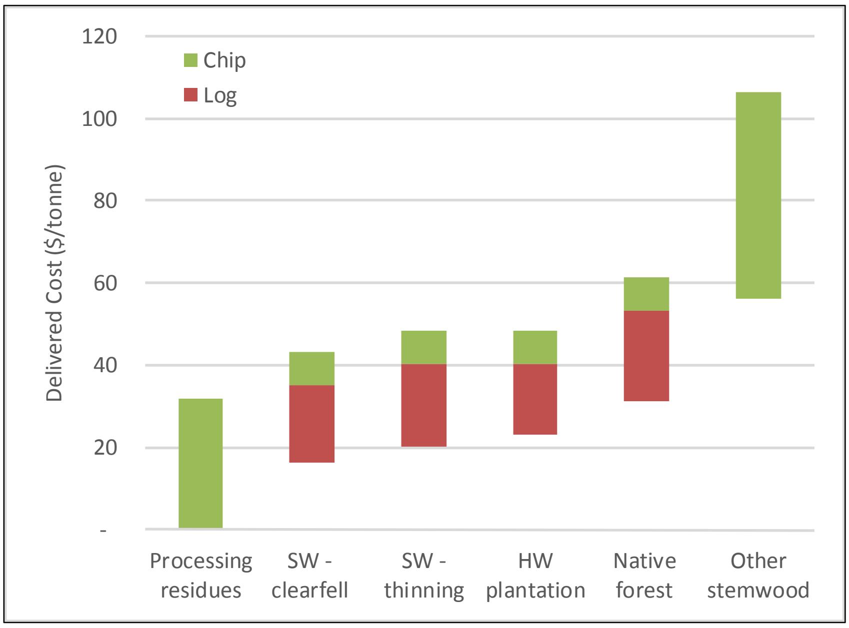
Figure 2-7 provides an indicative guide to delivered residue costs for various harvesting operations. Costs reflect the generic costs for Tasmanian operations. Unless specified, the lower bound is based on the harvest cost plus a haulage cost of 25 kilometre (km) with the upper bound the harvest cost plus a 75 km haulage distance. Harvesting costs are based on a cut to length log harvesting system. A uniform chipping cost of $8/tonne is shown separately and this may occur as part of the harvesting operation (in-field chipping) or following delivery of the logs to a static chipper. Other key assumptions are noted in Table 2-1.

Table 2-1: Summary of Delivered Cost Assumptions

Product Group	Key Assumptions for Defining Lower and Upper Bound
Processing residues	Chip – delivered cost presented in chip form Lower bound – assumes residues sold at zero stumpage Upper bound – assumes 75km cart for residues plus stumpage revenue of $20/tonne for the processor
Softwood clearfell	Upper and lower bound based on industry data for a broad productivity range (thinned and unthinned plantations)
Softwood thinning	Upper and lower bound based on industry data. First thinning operations typically have a higher cost than second or subsequent thinning
Hardwood plantation	Reflects an average cost range for hardwood plantations in Tasmania based on our understanding of plantation productivity
Native forest	Upper and lower bound based on industry data. Upper bound represents costs associated with use of a cable harvesting system
Other stemwood	Based on the costs associated with in-field chipping in very low productivity plantation stands (< 75 tonnes/ha) with a 20% loading for the difficulty associated with handling and collecting forest residues. Assumes all residues are chipped on-site

Source: Indufor (industry sources)

Figure 2-7: Indicative Delivered Residue Costs Based on a 25 km to 75 km Haulage Distance



Source: Indufor (industry sources)

Figure 2-7 shows that processing residues have the lowest delivered cost of all residue types. This is because the costs associated with transforming the log into wood products is absorbed by the primary processing operation. Residues are considered a byproduct of this operation. While processors will still seek to maximise the value of these byproducts, end markets will typically seek to attain these residues at little or no cost if the mill does not have the capacity to absorb them.

Logs from harvesting in plantations can generally be delivered for between $20-40/tonne depending on haulage distance. In this example the average haulage distance is between 25-75km. Where the delivery distance exceeds 75km, then the delivered cost for plantation logs would be close to or in excess of $40/tonne.

The higher logging cost for native forests reflects the greater level of variability compared to plantations and the more challenging harvesting conditions most contractors face. The upper bound reflects the high costs associated with steep slope harvesting. The average native forest harvesting cost would be at the lower end of this range.

It may be possible to collect some Other Stemwood volume for a lower cost than indicated in Figure 2-7, especially if it is concentrated around a central processing area. However, if recovered on a broad scale basis, the costs would be significant whether they are sourced from plantations or native forests.

3. PLYWOOD

3.1 Option Summary

Plywood is a major timber product consumed around the world for a range of internal, external structural and non-structural purposes. Current global consumption is around 100 million m^3 annually. While plywood has been in use for many decades, it was considered to be a product in general decline around the year 2000 as it lost market share to lower cost softwood panel products. Despite losing market share, plywood production and consumption has continued to grow, especially in China which is the world's largest producer and exporter of plywood.

Historically most of the plywood produced in the Asia Pacific region relied on large diameter tropical hardwood logs as a feedstock. Major plywood producer countries including Malaysia and Indonesia sourced these logs from natural forests. As the supply of tropical hardwood logs has declined, and low cost labour has become increasingly accessible in China and more recently Vietnam, a plywood industry based on small diameter hardwood plantation logs has emerged. This high labour, low capital model produces veneer sheets which are then sold to plymill factories who complete the plywood layup and cutting process. Chinese and Vietnamese plywood manufacturers use both domestically grown hardwood plantation logs and imported supplies. These logs are significantly smaller than traditional supplies and require different equipment for the peeling process.

The Chinese plywood sector utilises significant volumes of plantation eucalypt logs, including plantation grown *Eucalyptus nitens* logs from Tasmania. Low production costs allow this supply chain to be competitive despite the cost of importing logs from countries such as Australia. The competitiveness of this supply chain can be demonstrated through the export log price for hardwood logs which are currently comparable to prices paid for logs delivered to an Australian export chip mill.

With a domestic industry based primarily on softwood plywood production, Australia is a net importer of structural and non-structural plywood. Imports comprise a wide range of plywood products, reflecting the variety of potential end uses in the Australian market. With population growth underpinning demand for housing, especially intensive residential developments, Australian demand for plywood is expected to grow over the medium term.

Plywood manufacturing in Australia is established using a more traditional arrangement, with the process being capital intensive and requiring significantly lower labour inputs than observed in China or Vietnam. The small volume of hardwood plywood produced in Australia is based on large diameter hardwood logs sourced from native forests. Very little hardwood plantation material has been processed to date by the plywood sector in Australia and the understanding of the performance of plantation hardwoods is limited.

From a residues perspective, the most likely feedstock for a plywood mill in Tasmania would be sourced from hardwood plantations, most have which have been managed to produce pulpwood (i.e unpruned and unthinned). Peeling trials in Australia indicate the grade outturn of plywood from plantation grown *E. nitens* logs sourced from pulpwood plantations would be predominantly lower quality veneer more suited to plywood core material, rather than the higher value face veneer sheets. These properties could potentially be improved over time through targeted breeding programmes and optimizing the peeling and drying process.

A poor grade outturn makes the business case for domestic plywood production from plantations managed for pulpwood more challenging. While the cost to produce this type of plywood in Tasmania is higher than other international producers, its use by offshore processors suggests it has some future, potentially in veneer form, where it can be combined with a higher quality face and back veneer sheet to produce a more valuable plywood product. Regional veneer markets are expanding rapidly, particularly in countries such as China and India which are importing large volumes of core veneer material.

3.2 Plywood Markets

Plywood production involves pressing together a number of thin veneer sheets of wood to produce a panel. Plywood differs from other veneer based panels in that it is made up of an odd number of veneers (ply's) layered on top of one another with the grain perpendicular to the preceding sheet.

Plywood can be manufactured from a range of log types. This assessment focuses on the potential utilisation of small diameter hardwood logs that would otherwise be classified as pulpwood and not currently part of the contracted supply from native forests. The potential for peeling large diameter, long rotation hardwood plantation logs, which are typically better suited to peeling, is beyond the scope of this report as these are not classified as residue logs.

Global Plywood Markets

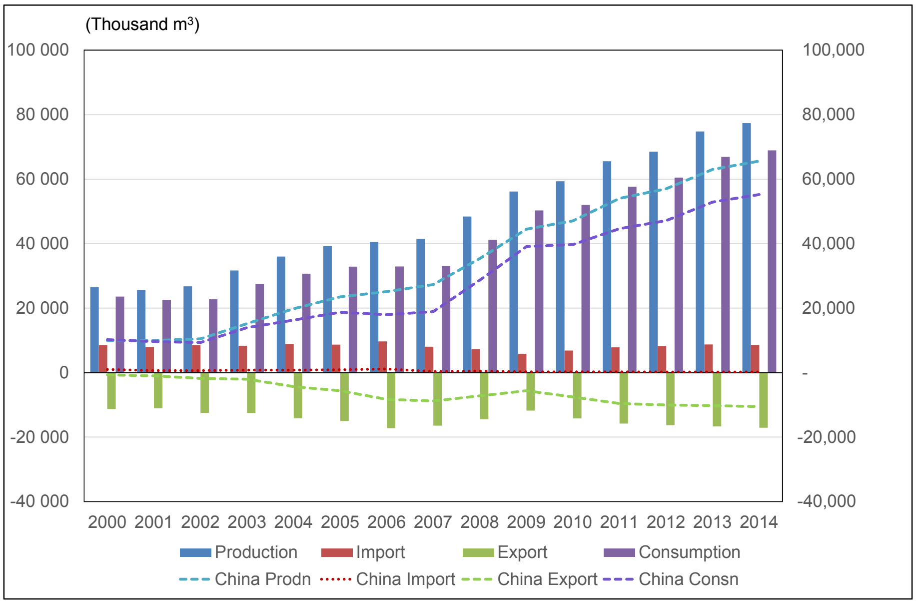
Annual plywood consumption globally is between 100 and 105 million m^3. Asia is a major producer and consumer of plywood and one of the few regions around the world where consumption and production of plywood has been increasing substantially. This has largely been a result of increased plywood production and demand in China (Figure 3-1). Plywood consumption in the region reached 79 million m^3 in 2014, with China accounting for 65 million m^3. Asia is also the world's largest plywood exporting region with more than 17 million m^3 of plywood exported, most of it coming from China.

While plywood production in other countries within the region has been declining, either as a result of shrinking markets (Japan) or shrinking raw material availability (Thailand, Malaysia, Philippines and Indonesia), China's output year on year has continued to expand with the growth of its domestic economy. This growth has resulted in two important regional developments in plywood production:

- A changing approach to plywood manufacture; and
- A shift toward utilising plantation wood and small dimension logs in particular.

Plywood production in Vietnam has also expanded rapidly, largely as a result of the adoption of Chinese plywood production approaches and the relative abundance of small diameter hardwood plantation logs which would otherwise be sold as pulpwood.

Figure 3-1: Asian Plywood Production, Consumption and Trade[1,2]



Note: 1) Data does not include production, consumption and trade from within the Oceania/Pacific region
2) Data includes Laminated Veneer Lumber

Source: Global Trade Atlas

Plywood can be manufactured from hardwood or softwood logs. In 2014 China imported around 12 million tonnes of hardwood logs, with approximately two thirds sourced from natural tropical hardwood forests in Papua New Guinea, Solomon Islands, Africa and South East Asia. These logs are used for a variety of purposes, including the production of plywood. Australia currently exports around 150-250,000m^3 of hardwood logs to China per year. These are primarily low quality logs sourced from native forests as well as *E. globulus* plantations in the Green Triangle and southwest Western Australia and *E. nitens* plantations in Tasmania.

Australian Plywood Markets

Plywood is a significant market in Australia where it is used extensively for residential construction and industrial formwork. Over the last 20 years production of plywood in Australia has fluctuated, but apparent consumption has increased at an average rate of 6% per year over the long term (Figure 3-2).

The bulk of the plywood manufactured in Australia is based on softwood, with the largest facility operated by Carter Holt Harvey at Myrtleford. Australian hardwood plywood is used for industrial and commercial formwork where its durability and re-usability is valued.

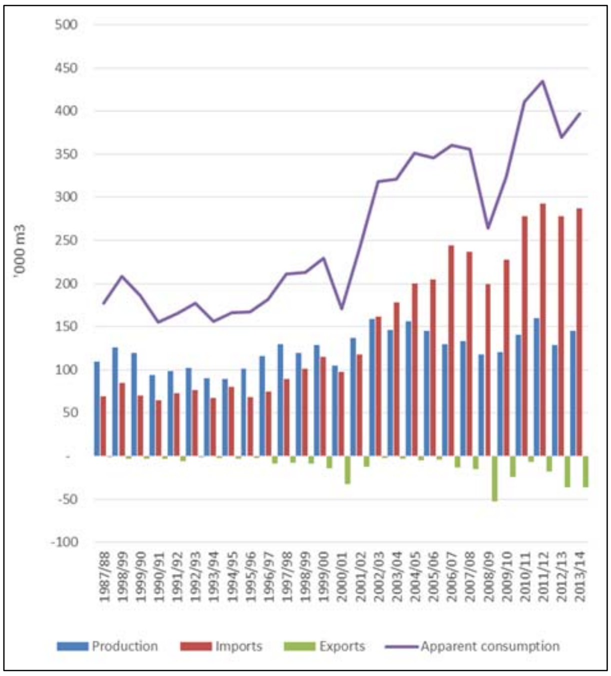
Prior to 2015 the only hardwood plywood produced in Australia was by Big River Group's Grafton mill in NSW. Hardwood plywood from this mill currently accounts for less than 10% of total Australian production. In August 2015, Ta Ann Tasmania opened a new hardwood plywood mill at Smithton which has the capacity to produce up to 36,000m^3 of plywood/ year. The mill is expected to produce a range of structural and appearance grade plywood products for the Australian market. The new mill represents an extension to Ta Ann Tasmania's main activity which is the production of veneer from its two international scale operations. Collectively the sites have a contracted supply of around 157,000m^3 of peeler logs/ year, but have a higher production capacity. The veneer sheets are exported to Malaysia for flooring, plywood and LVL production.

Australia imports plywood from a number of different countries. Plywood imports are classified as:

- **Overlaid** – plywood has an overlay of material on its outer surface to increase durability or for other aesthetic purposes. This includes the use of paper impregnated with phenolic resins for use in concrete formwork (formply), fibreglass overlays for waterproofing (boat building), fibre cement sheet overlays (fire resistance) and decorative overlays such as vinyl and stainless steel;
- **Structural** - can be produced from either softwood or hardwood and is often treated with preservative for use in exposed exterior applications. Structural plywood manufactured to the AS/NZS 2269 Standard is suitable for use in all permanent structural applications;
- **Interior glueline** - intended for non-structural interior applications where a high quality finish is required. Typical applications include wall paneling, ceiling linings, furniture and interior door skins. The glue bond in this type of plywood is not suitable for full weather exposure or damp environments; and
- **Other** – where the type of plywood is not specified.

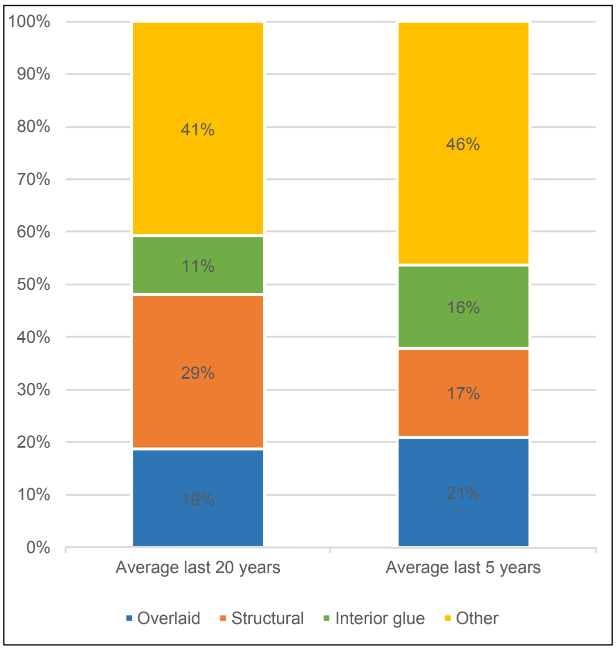
Historically, plywood classified as 'Other' has made up the majority of plywood imports with China identified as the major supplier followed by New Zealand (most likely LVL), Malaysia and Indonesia (hardwood plywood) (Figure 3-3). Where plywood type is identified, there has been a trend away from the import of structural plywood. This has been offset by an increase in the proportion of interior use (interior glue) and overlaid plywood imports.

Figure 3-2: Apparent Consumption of Plywood in Australia



Source: ABARES (2015)

Figure 3-3: Proportion of Australian Plywood Imports by Type



Source: ABARES (2015)

The increase in non-structural plywood imports in recent years reflects a proliferation of uses for overlaid plywood and its increased usage in interior appearance applications in line with changes in the housing construction and renovation markets. The majority of overlaid plywood is sourced from Indonesia and China, with China also being a key supplier of interior use plywood.

Plywood Price Trends

Regional plywood prices vary considerably depending on species, veneer quality and grade, and intended purpose. Current prices in India range from USD300/m^3 to USD700/m^3. Plywood with a eucalyptus core and tropical hardwood face and back is currently trading at between USD315-340/m^3 CIF for 18mm ply.

In China plywood pricing for furniture and decorative uses is presently ranging from RMB135- 138 per sheet for 18mm panels (USD410-420/m^3). Plywood for concrete formwork can be RMB100 per sheet (USD300/m^3).

Plywood made from tropical hardwood in Malaysia or Indonesia may still command prices over USD400/m^3 FOB. However lower quality plywood made from plantation eucalypts, acacias or albizia tends to be sold more in the order of USD200-300/m^3.

Prices in Vietnam perhaps best reflect the expectation for plywood made from small diameter plantation eucalyptus and acacia. Current plywood prices range between USD250-300/m^3 FOB for standard grades manufactured from small diameter acacia or eucalypt logs. Prices for packaging grade plywood are lower again at around USD200-250/m^3.

The price of plywood in Australia declined significantly from the beginning of 2009 through to late 2013 (Figure 3-4). A major driver for decreasing plywood C/D grade[1] prices over this period

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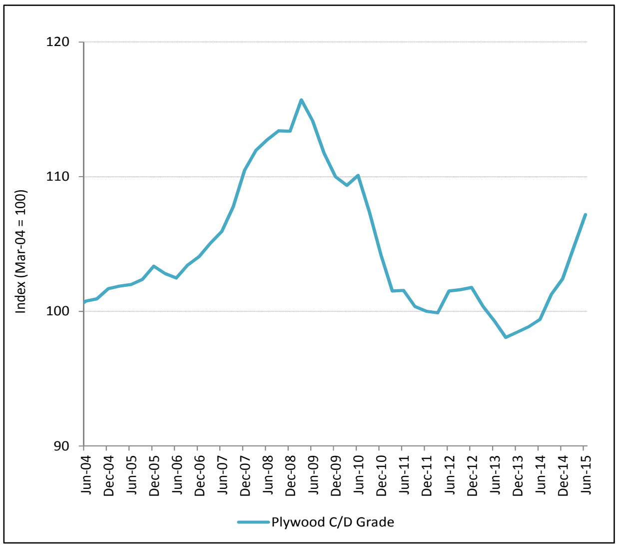
[1] In Australia C/D grade is a low grade softwood plywood with comparable properties to plywood produced from plantation eucalypts

was a downturn in the Australian housing market and the competitiveness of imported products, particularly from Chile. The nominal price has since stabilised and started to trend upwards over last two years reflecting an improvement in domestic construction activity.

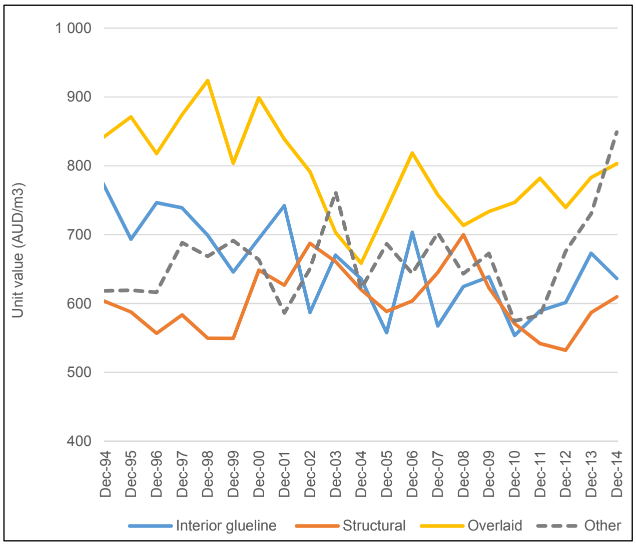
Figure 3-5 shows overlaid plywood is the most expensive of the plywood imports, followed by interior glueline then structural plywood. Plywood import prices tend to be cyclical but since 2004 have traded within a reasonably defined band. Imports classified as 'Other' have no specified end use and this category includes a range of plywood configurations.

Figure 3-4: Nominal Australian Plywood Price Index, Softwood, C/D Grade



Source: GTIS.
Note: Includes both domestically produced and imported plywood prices

Figure 3-5: Nominal Australian Import Prices by Plywood Type*



Source: ABARES (2015)

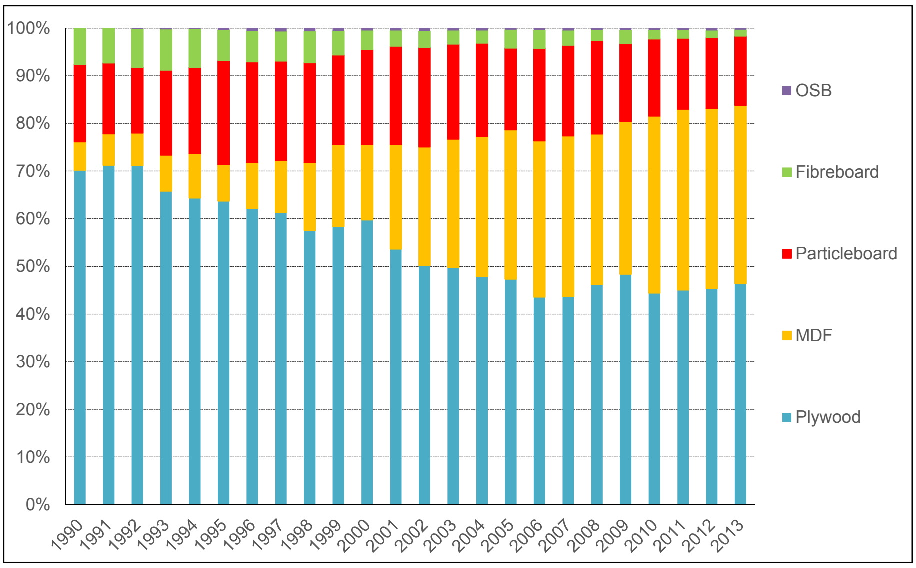
* The end use for 'Other' is not specified

The Outlook for Plywood Demand

Regional Outlook

In the year 2000, the view point of many in the panel industry was that plywood was a 'sunset' industry, based on its declining market share through substitution by lower cost softwood panel products such as OSB, particleboard and MDF, and the perceived decline in the availability of tropical hardwood logs. However, as Figure 3-6 shows plywood has reached a point where it has been able to maintain its market share in the Asia Pacific region. While this would imply static demand, Figure 3-1 shows that in volume terms plywood consumption has continued to expand in the region.

Figure 3-6: Panel Consumption Trends in the Asia Pacific Region



The continued production and use of plywood owes much to the use of the product in construction and industrial applications in Asia's fast growing economies. Plywood is light and strong, properties that are well suited to applications such as concrete formwork, packaging, interior joinery and furniture. In some applications (formwork), plywood can be re-used a number of times.

Provided Asian economies continue to grow and develop, regional plywood demand is expected to remain solid. Substitution pressures are likely to continue (particularly in interior and furniture applications) but major regional trends have already largely 'played out'. The expectation is for continued growth in plywood production and demand.

Australian Outlook

Demand for plywood in Australia is strongly linked to the status of the construction sector. Further intensification of residential development in the metropolitan centres of Australia, through construction of high rise and low rise apartment developments and multi-unit dwellings, should impact positively on demand for plywood, especially for concrete formwork. In these uses, steel formwork is a key competitor and therefore steel pricing influences the potential for substitution. These trends in construction markets are expected to continue underpinning demand for plywood, particularly for structural applications.

3.3 Technology and Proponents for Production of Plywood

There are multiple approaches to producing plywood with the preferred approach determined by the physical parameters of the raw material being peeled and the particular economic environment in which the processing takes place.

The traditional method for making plywood occurs under a single roof. A 120,000m^3/year line can employ up to 1,700 people in Indonesia and roughly half that number in Malaysia. This method of producing plywood is both capital and labour intensive. But it is an efficient and practical approach where scale and quality is important and sufficient quantities of readily peelable large dimension hardwood logs are available.

More recently an alternative approach has evolved out of the declining availability of tropical hardwood logs leading to the processing of veneers from logs with a small end diameter of just 8 cm. Another distinctive feature of this approach is the bypassing of the high level of capital investment required under the conventional approach. China has built a plywood industry of enormous proportions around thousands of small businesses operated mostly by individuals or families. The Chinese model is based on the concept of disaggregating the two main stages of plywood manufacture. Log peeling (Figure 3-7) and veneer drying (Figure 3-8) is typically handled by one business. The air dried veneers are then sold to plywood manufacturers who upgrade, glue, press and finish the plywood panels. The two facilities are often physically separated from each other, effectively decoupling the manufacturing process.

Figure 3-7: Veneer Production in Guigang Province, China

Figure 3-8: Veneer Drying in Fields Around Guigang Province, China

Note small size of logs to be peeled in the background

This approach is viable when the logs can be manually handled onto a peeling lathe. The equipment for veneer production uses mini rotary and small spindleless lathes, manual veneer handling, air drying or static press drying, single glue spreaders and small scale multi opening presses). It is very labour intensive, but requires far less capital investment than a conventional large scale plymill.

With the decline in tropical hardwood log availability in Indonesia, the plywood industry there has shifted to utilising albizia (a local species grown in abundance by smallholders and farmers) for plywood manufacture. Indonesian plywood producers have tended to hybridise their operations, retaining the conventional mill concept (and in many cases the mill itself) while replacing elements in the process, including the use of mini rotary lathes, spindleless lathes and static drying presses. Nonetheless conventional approaches are retained for the production of thin face and back veneer which are still predominantly sourced from tropical hardwoods.

Within Malaysia and Indonesia, some companies have adopted a version of the disaggregated plywood process concept, by developing satellite veneer mills in reasonable proximity to the log resource and supplying dried veneer to a central plywood mill which lays up, glues and presses the veneer into plywood. Although generally relatively small scale (30-60,000m^3/year in Indonesia and up to 100,000m^3/year in Malaysia) these satellite mills are still considerably larger than the family run Chinese equivalent. Such facilities utilise essentially Chinese made equipment and produce predominantly short core veneer.

Inline processing is another alternative in plywood manufacture. In recent years Raute have developed the inline processing concept where all the necessary plywood making components are aligned in a single continuous production line[2]. Designed more with small diameter softwood logs in mind, such a process also benefits from the restricted range in veneer thicknesses that are typically peeled when making plywood in Northern Europe. Focus is on volume production and quality. These lines are not particularly labour intensive but like the Meinan Ariste lathe and the conventional plywood process, they are capital intensive.

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[2] The conventional South East Asian plywood mill where all the components to make plywood are present but isolated in space from one another, are not necessarily arranged for efficient process flow

Table 3-1 summarises the attributes of the various manufacturing approaches. While the approach taken in China will almost certainly be appropriate for processing small diameter Tasmanian peeler logs, the labour requirement would not make this a practical option at scale. The inline option is more likely to be suited to Tasmania, provided the peeling lathes are designed to handle the characteristics of the available feedstock.

Table 3-1: Summary of Approaches to Processing Plywood

Approach	Labour Intensity	Capital Intensity	Log Size Type
Conventional Asian	High	High	Large diameter natural tropical hardwood logs
Chinese	Very high	Low	Very small diameter logs
Satellite and hybrid models	High	Moderate	Small to medium plantation and large diameter tropical hardwood logs
Inline (e.g. Raute)	Low	Very high	Relatively small diameter logs

3.4 Social and Environmental Considerations

Environment

Plywood logs would be sourced as an additional log sort from within existing harvesting operations. Therefore producing peeler logs from native forests or plantations is unlikely to lead to any intensification in harvesting.

Plywood produced from certified forests in Australia would provide a robust chain of custody for consumers compared to plywood sourced from tropical hardwood forests where logs may have an unknown provenance.

The resin used in plywood manufacture often contains formaldehyde however the amount of resin used is substantially less than for composite panel products (~2% by weight, compared with ~10% for particleboard and MDF). The use of low emission glues mean formaldehyde emissions in Australian plywood operations are maintained below recommended health levels in accordance with Worksafe Australia regulations[3].

In manufacturing plants, modern dust extraction and management systems mean that risks to workers and to the broader environment by formaldehyde, as well as Volatile Organic Compounds (VOCs) and carbon monoxide (produced during the drying process) are minimised.

Other potential environmental impacts from veneer or plywood production include noise, increased traffic and run-off of dust and petroleum into stormwater which would all require management by the company and engagement with government and the broader public.

Social

A plywood mill would be expected to directly employ around 50-100 people. Its location would be close to the resource so it would improve regional employment opportunities.

Some of the economic benefits to Tasmania associated with the development of a greenfield plywood operation based on hardwood plantations include:

- Increased domestic economic activity and port throughput;
- Broadening of Tasmania's manufacturing skill base; and
- Diversifying markets for Tasmanian forest products.

[3] Engineered Wood Products Association of Australia (2012): Understanding the characteristics of plywood and LVL, and how these products are used

3.5 Prospects for Plywood Production in Tasmania

Plywood represents a potential market for Tasmanian residues because:

- Logs from hardwood plantations in Tasmania are already being utilised for plywood production in China. Plywood produced from plantation grown hardwood is readily accepted in Asian markets;
- Tasmania has a well-established veneer production process. However, the current configuration of these facilities is designed to peel larger diameter native forest logs than would be produced from hardwood plantations; and
- Australia is a net importer of plywood, indicating there may be potential scope for a degree of substitution from a domestic source of supply. Countenancing this potential is the additional supply arising from the recently commissioned Ta Ann plywood plant.

End Markets and Feedstock Availability

Tasmania represents a very small proportion of Australia's total construction market. Therefore only small quantities of plywood are likely to be consumed within the state. Given the volume of plywood imported into Australia, there would appear to be potential for construction of further capacity in Australia to meet some of the domestic demand. This is already occurring with the recent completion of the Ta Ann plymill in 2015. Data on the extent to which this new facility is displacing plywood imports is not yet apparent.

Within Australia, the peeling of small diameter eucalypt logs has only been undertaken at a trial scale. McGavin *et al.* (2014)[4] peeled a sample of 20-21 year old *E. nitens*. This is older than what would be a typical harvest age of around 15 years for a pulpwood plantation in Tasmania. Veneer was graded to Australia/ New Zealand Standards for structural plywood which identifies four veneer grades (A–D) of decreasing quality. Veneer sheets that fail to make D grade are defined as rejects. Grade recovery from the trial was 11% B grade, 15% C grade, 68% D grade and 6% reject. Encased knots (44%) and bark or decay (41%) were the greatest source of veneer downgrade.

Another peeling trial using 16 year old *E. nitens* found the recovery of D grade was 49% with the remainder classified as reject[5]. The plywood produced from these logs also had poor shear values which would limit its usefulness for structural products. These findings are consistent with other trials completed by Ta Ann which found key limiting factors to peeling plantation *E. nitens* to be the frequency and orientation of bark encased knots. While knot size was acceptable, the frequency of knots was very high due to the lack of branch shedding.

The results from these peeling trials [4,5,6] suggest it is likely that pulp grade eucalypt logs would mostly produce veneers of core grade quality and even then the veneer sheets may still require manual or machine assisted upgrading to obtain sheets of the appropriate dimensions for making plywood. The face and back veneer would most likely need to be obtained from another better quality log.

Plywood produced from these small diameter logs are likely to find uses in packaging and in furniture where the plywood is not visible. Other non-structural applications could include hoarding (with the addition of a higher quality face and back veneer), and some uses in joinery and cabinetry, though in the case of the latter close consideration of veneer properties will be

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[4] McGavin R., Bailleres H., Lane F., Fehrmann J., Ozarska B.(2014) Veneer grade analysis of early to mid-rotation plantation Eucaluptus species in Australia. Bioresources 9 (4), 6562-6581.

[5] Farrell R., Blum S., Williams D. Blackburn D.(2011) The potential to recover higher value veneer products from fibre managed plantation eucalypts and broaden market opportunities for this resource: Part A; Forest & Wood Products Australia

[6] Blakemore P., Morrow A., Washusen R., Harwood C., Wood M., Ngo, D. (2010) Technical Report 202 Evaluation of thin-section quarter-sawn boards and rotary veneer from plantation-grown *Eucalyptus nitens*. Cooperative Research Centre for Forestry.

required. It is unlikely veneer produced from this resource could be converted into concrete forming plywood[7], exterior cladding or other interior applications where visual appearance is important.

In terms of the potential feedstock available for a plymill development in Tasmania:

- Processing residues and Other Stemwood are not suitable as a feedstock;
- Some softwood pulpwood may be suitable, but pulp logs typically have poor form or large branches which would render them unsuitable for peeling. Logs from commercial thinning may have the appropriate dimensions, but the low density of this material due to its age would make its suitability for plywood questionable; and
- Straight logs sourced from regrowth native forests that are not suitable for sawing are currently supplied to Ta Ann's veneer mills. The current minimum small end diameter (sed) for regrowth peeler logs is 20 cm, although larger logs are preferred. Therefore, any additional supply would be between the minimum existing small end log diameter of 20 cm and 14 cm, the minimum small end log diameter for plantation peeler logs.

This means the bulk of the supply of peeler logs would be sourced from Tasmania's hardwood plantations. Plantation *E. nitens* is already an accepted plywood species internationally with trade data indicating a steady supply of hardwood logs from Australia to China. The specification for a typical export hardwood peeler log is:

- Sweep (allowable bend in the log) of less than ¼ of the small end diameter with a maximum 5cm deviation from the centre line;
- Maximum branch size 5cm;
- Minimum small end diameter 14cm; and
- Log length 5m.

The volume of plantation peeler grade logs available in Tasmania would depend on the log specification, particularly the small end diameter and the required straightness of the stem. The typical recovery of peeler logs from hardwood pulpwood plantations in Australia based on the log specification described above ranges from 20%-40% where stand volume exceeds 200 m^3/ha. The recovery of these logs becomes uneconomic once stand volume falls much below 200 m^3/ha. This yield is comparable to Tasmanian *E. nitens* with plantations in the North West region generally performing better than those in the North East or South East regions.

Figure 3-9 shows the estimated volume potentially available by sub-region assuming an average peeler yield of 40% for the North West region and a peeler outturn of 25% for the North East and South East regions.

It must be recognised that the existing *E. nitens* plantation estate is highly variable with much of the area unthinned and unpruned especially plantations established under a Managed Investment Scheme structure. There are concerns within industry as to whether this material can be economically peeled and further research and development would appear to be warranted.

In addition to plantation pulpwood, a small proportion of native forest pulpwood may also meet these specifications. Native regrowth forests tend to be more variable than plantations and comprise a broader range of log sizes. Assuming logs with a sed greater than 20 cm are already supplied to Ta Ann, only a small volume is likely to be available between 14 cm and 20 cm. Based on other native forest assessments of similar log grades it is estimated that 5% of the pulpwood derived from native forests could meet the specification for a small diameter peeler log.

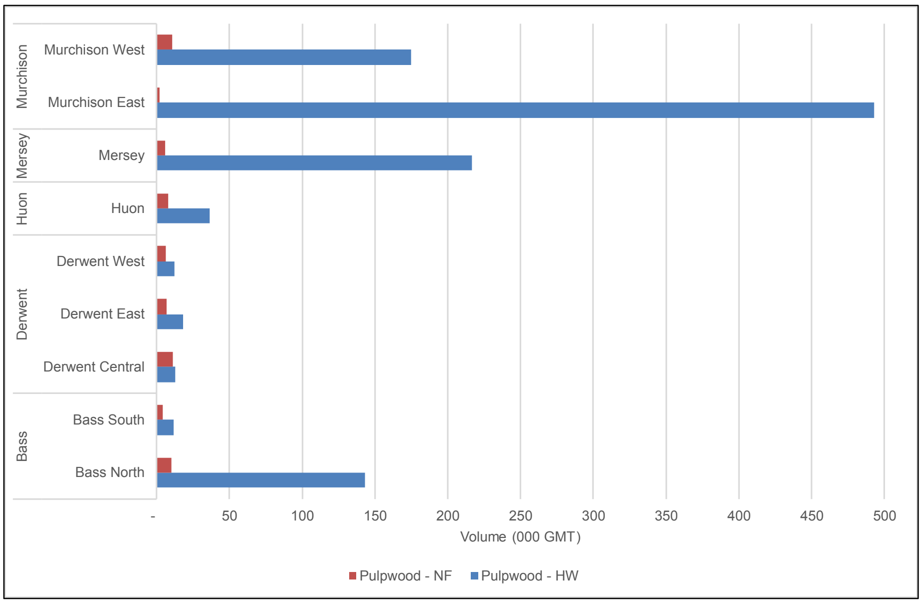
The greatest concentration of peeler volume occurs in the Murchison and Mersey regions. They have the largest hardwood plantation area and generally have superior growth rates compared

[7] Of a standard acceptable in Australia, though it is understood such plywood is used in this application in China

to the other regions. Based on the outturn assumptions noted above, these regions have the potential to supply up to 600 000 GMT/year of peeler logs from existing hardwood plantations in the short term.

The Bass region could have the potential to supply more than 150 000 GMT/year of peeler logs. The Huon and Derwent regions have limited capacity, with each region estimated to have less than 100 000 GMT/year of small diameter peeler logs available. Only a modest volume is expected to arise from native forests in any region as any revision to the existing peeler log specification would only result in a marginal increase in additional supply.

Figure 3-9: Estimated Availability of Small Diameter Peeler Logs from Tasmanian Residues



Source: FT, PFT, Indufor

As noted previously, these estimates are based on percentage of peeler logs arising from hardwood plantations managed for the production of pulpwood. The estimates do not include large diameter logs that would be available from long rotation hardwood sawlog plantations that had been pruned and thinned. Logs from these plantations are likely to produce a higher quality veneer than from unpruned and unthinned pulpwood plantations.

Economic Considerations

Plywood manufacturing starts with the log being debarked, cut into billets of the desired length and then rotary peeled. The resulting veneers are dried before being upgraded (to remove defects), covered (spread) with glue, placed into a hot press where heat and pressure set the glue and bind the veneer sheets together. The resulting panels are then trimmed, sanded and packed for warehousing and distribution to the customer (Figure 3-10).

Figure 3-10: Plywood Manufacturing Process

Analysis of the various plywood production methods suggests the inline approach would provide the best fit for manufacturing plywood in Tasmania. The small veneer producing business model of China relies on labour costs that are far lower than the Australian minimum wage and the resource is not suited to a mill designed to accommodate large diameter logs.

Raute has the closest configuration to providing an inline processing facility for making veneer and producing plywood. Raute has for some time been promoting inline veneer production designed to produce veneer of a standard (2.6mm) thickness. Such lines can peel veneer thinner and have been designed to process relatively small dimension logs (but not down to 8cm). The Raute system is designed for large volume production and high process throughput.

The Raute inline process is not a 'complete' turnkey solution with boilers, water treatment facilities, and testing facilities requiring consideration as part of the capital cost associated with establishing a plymill. Assuming such an inline processing facility can be designed to process residue logs, at a capacity of around 40,000m^3/year plywood output, the capital investment cost is estimated to be around USD40 million, covering all civil construction, equipment, mobile plant and installation. The scale of any potential development would be based on aligning resource availability with transport distance to the mill. It could therefore be larger or smaller than indicated.

Table 3-2 summarises the estimated production costs other than the raw material based on a mill producing 40,000m^3/year of plywood. This data has been compiled based on plymill studies in the Asia and Oceania regions over a number of years.

Table 3-2: Estimated Plywood Production Costs

Parameter		**USD/m^3 Plywood**	**AUD/m^3 Plywood**
Capital costs	Interest (50% debt) & depreciation (20yrs)	80-90	107-120
Variable costs	Energy and utilities	17-25	23-33
	Consumables and packaging materials	15-20	20-27
	Other variable	6-10	8-13
Fixed costs	Personnel	25-35	33-47
	Administration	5-8	7-11
	Repair and maintenance	10-15	13-20
	Other fixed	10-15	13-20
Total		**168-218**	**224-290**

Source: Indufor

A key cost in making plywood is in the raw material. To be competitive a Tasmanian plymill would need to offer at least the equivalent export peeler log price (less any transport differential benefit) to be attractive to a forest grower. Discussions with Chinese processors peeling plantation eucalypts in Guangxi Province indicate the current FOB price for hardwood plantation logs loaded on a ship in an Australian port is in the vicinity of USD83-86/m^3. Taking into account port handling and storage costs this equates to an indicative wharf gate price range of AUD89-93/m^3.

Assuming a conversion factor of 0.35m^3 of plywood per m^3 of log input, the log price is equivalent to AUD250-260/m^3 of plywood. This conversion factor is low for a modern plymill due to the significant amount of defect removal that is likely to be required when using *E. nitens* plantation material. Its tendency to retain branches mean a higher level of knot defects, especially bark encased knots, compared to other eucalypt species such as *E. grandis* which naturally shed their branches as they grow. This conversion factor is critical to the viability of a peeling operation as a conversion factor of 0.45m^3 of plywood per m^3 of log input reduces log costs to around AUD200/m^3 of plywood produced, a 22% reduction.

Most of the *E.nitens* plantation estate is in private ownership and the decision to sell logs suitable for plywood production would be at the discretion of those growers. The market for these logs would be competitive with a floor price determined by alternative markets which include both export peeler logs as well as hardwood woodchip markets.

The combination of hardwood log prices and mill operating costs indicates a total production cost range in the vicinity of AUD480-550/m^3 or USD355-415/m^3. Costs associated with transportation of the finished product, warehousing, containerizing, port storage, shipping and transport to end markets would be additional.

While these production costs are higher than international benchmarks, they are still lower than the landed cost of plywood imported into Australia. However, the low outturn of high quality veneer grades is likely to be a barrier to the viability of such a project. McGavin *et al* (2014) notes that the Engineered Wood Product Association of Australia suggest at least 30-40% of the expected outturn is required to be C grade or better to allow for saleable product manufacture. Trials to date indicate very little, if any, C grade or better material could be realised from plantations harvested at around age 15 years. Therefore a plymill facility in Tasmania would need to source higher quality veneer sheets domestically or import them which would adversely impact on the cost competitiveness of the production process.

An alternative approach would be to produce veneer sheets which could then be sold into domestic or export markets. This opportunity is discussed further in the following section.

Pathway for Residue Utilisation

Australian demand for plywood has expanded in recent years, with approximately 275,000m^3 imported in 2014. Imported plywood is used for a range of structural and non-structural purposes, with most growth occurring in non-structural applications. Tasmania's construction market represents a very small proportion of national demand.

While plantation grown *E.nitens* is used to produce plywood overseas, its utilisation to date in Australia is limited to a small number of peeling trials. This research indicates that knots, bark and decay are a major source of defects that are likely to limit its potential use in the short term to non-structural applications. In addition, the strength (elasticity) of plywood produced from this material is lower than market requirements. These properties could potentially be improved over time through targeted breeding programmes and optimizing the peeling and drying process.

The lack of face veneer recovery means a stand-alone mill based on pulpwood plantation logs would be challenging. However, it may be suitable as core veneer with a face veneer or other overlay added to the ply.

One potential avenue to gain further insight into the potential capabilities of *E.nitens* plywood is to investigate the substantial operations in China which already specialise in peeling very small diameter (8-14cm sed) hardwood logs. This may also provide an opportunity to assess how the logs perform using different processing equipment.

Another potential pathway is to produce veneer in Tasmania which could then be on-sold to domestic or international markets. Expansion in the production of plywood from hardwood plantation material has led to an increase in the Asia Pacific veneer trade. This trade is developing in countries such as Indonesia, Vietnam and the Philippines but has substantial potential in major plywood producing countries such as India and China:

- **China** – veneer imports have been increasing substantially in recent years. In 2014 just over 666 million m^2 of veneer were imported with imports growing rapidly at 50% per annum over the last five years. Just over 90% of veneer imported to China is core veneer. Face and back veneer imports are likely to constitute no more than 3% of veneer imports. In contrast less than 10% of Chinese veneer exports are believed to be core veneer.
- **India** – the plywood industry in India is understood to be substantial although accurate data is not available. It is estimated that some 2.5 million m^3 of plywood is currently being produced in-country. Changes in raw material availability has already prompted the Indian plywood industry to relocate some facilities to countries like Myanmar to be close to the resource but in some instances plymills have been forced to close down. This has led to renewed interest in plantation logs for plywood production. In 2014 it is estimated that around 123 million m^2 of veneer was exported to India with imports growing at a rate of 46% per annum over the last five years. Around 55% to 65% of all veneers currently supplied to India are understood to be core veneer with the balance higher quality face and back veneer.

In situations where there has been a decoupling of the peeling process and plywood manufacture, opportunities may exist where low cost core veneer could potentially be supplied to plywood manufacturers. The fragmented nature of veneer production in China means there is substantial variability in the feedstock resulting in variable plywood quality. Entry to this market would require an alignment between the wood properties being sought by the purchaser and the quality of the veneer provided by the supplier.

Eucalypt veneer is produced in large quantities in Guangxi Province. The price for air-dried core eucalyptus veneer in the region is currently around RMB1,200/m^3 (USD193/m^3) ex-mill. This feedstock is comparable to the material that would be produced from Tasmanian *E.nitens* plantations.

While the existing plymills in Tasmania could potentially process plantation logs, the mill design is not optimised for handling small diameter logs. Therefore any veneer manufacturing based on plantation hardwood pulp logs would be complementary to, rather than in competition with existing operations.

The capital cost to develop a greenfields veneer facility would depend on the extent to which the veneer is dried (to a moisture content of 8-12%) and upgraded (defect removal) prior to shipping. A veneer plant with a capacity to produce 10,000 m^3/year of veneer would have an investment cost of USD3-12 million, but is unlikely to have sufficient scale to be competitive. A veneer mill with capacity to produce 50,000 m^3/year would cost between USD20-30 million while a mill producing 100,000 m^3/year of veneer would cost USD35-60 million. Operating costs would also be lower than for a plymill.

Estimates of peeler log availability indicate the potential to realise a substantial volume of peeler logs particularly in the Murchison (>650,000m^3/year) and Mersey regions (>250 000 m^3/year).

Table 3-3 provides a summary of the key considerations for further development of the plywood (and possibly veneer) sector.

Table 3-3: Summary of Key Considerations for Plywood Development in Tasmania

Criteria	Key Considerations
Key Success Factors	Strong existing plywood processing capacity/ knowledge in Tasmania Supply chain for veneer and plywood already well developed Substantial log volume likely to be available
Key Challenges	Quality of plantation grown *E.nitens* Product meeting building standards Competing in international markets against low cost producers
Barriers to Entry	Log quality – quality of plantation logs unproven in an Australian context Securing sufficient supply Substantial capital investment likely to be required to acquire equipment suited to peeling small diameter plantation logs
Collaborators	Existing processors – further expansion of production capacity Forest growers – seeking to expand markets Asian or Indian plywood manufacturers seeking to expand resource supply
Competitors	Hardwood pulpwood exporters Existing processors – if a plymill is set up independently of existing mills Plywood importers and export markets
Policy Considerations	Nothing specific identified
Potential Timeframes for Further Development	Small log peeling technology is already well developed Further trials required to develop optimal peeling/drying techniques and appropriate end uses for the existing *E.nitens* resource

4. GLULAM / CROSS LAMINATED TIMBER

4.1 Option Summary

Glue laminated (glulam) timber and Cross Laminated Timber (CLT) are engineered wood products used in high strength column, beam and wall construction markets as an alternative to steel and concrete construction. Glulam has been in use for many decades. It is visually attractive as well as providing structural values. CLT is a more recent product that provides differing functional uses compared to steel and concrete construction. For CLT these differing functions include enhanced sound acoustics and thermal properties where CLT is used as a wall, ceiling and floor substrate.

Glulam is manufactured extensively around the world with global consumption in 2013 of around five million cubic metres. CLT demand has grown significantly over the past decade, particularly in European markets. This growth in CLT uses occurs through revision of building designs and building construction methods, as key CLT benefits arise through precision building design and then significant reductions in construction time and labour costs.

Glulam is produced in small quantities in Australia using plantation softwood (Queensland) and native Victorian ash eucalypt species which are very similar to native Tasmanian eucalypts. The end products are sold into a range of niche markets. CLT use in Australia has been limited, with two multi-storey buildings completed in Melbourne. The CLT for these projects was sourced from European producers. In contrast, the Christchurch earthquake reconstruction has underpinned the development of a CLT manufacturer Xlam based in New Zealand.

The potential for CLT is significant, given its end uses include detached housing, multi-residential and non-residential construction. With the continued trend towards multi-residential, multi-storey housing in Australian, CLT and to a lesser extent glulam has the potential to capture part of this market from the steel and concrete alternatives. Depending on the potential for CLT to penetrate this market, CLT demand in Australia could increase significantly.

Construction cost assessments using glulam and CLT indicate both are price competitive in a range of residential and non-residential building types. While glulam is well understood, CLT requires a reconsideration of building design and construction approaches.

Any glulam development would be relatively small in scale and most likely located within a sawmill. CLT scale is relatively flexible and can be of relatively low capital cost. A hardwood glulam or CLT plant at the larger end of the scale spectrum would most likely require supply from multiple mills.

Current CLT production is based on softwood timber, capturing benefits in aligning lighter timber weight with increasing load bearing capacity in the finished product. A hardwood CLT product arising from Tasmanian hardwood residues would require extensive R&D to confirm the feasibility of production and seek to capitalise on its differing strength and weight characteristics. In addition revisions to the construction code and greater familiarity with the use of CLT and glulam for construction would be key components to stimulating greater consumption and realizing the potential to gain further efficiencies through the supply chain.

4.2 Heavy Structural Timber Markets

CLT and glulam are produced by bonding and pressing multiple layers of lumber together to produce large dimension panels and lumber products.

Glulam products are generally marketed as high strength beams or columns. Large CLT panels are used in an integrated operation where they are custom sawn for prefabricated housing or multi-storey apartment construction.

These large dimension wooden panels and lumber products are suitable for use in heavy construction, such as multi-storey buildings and large spans in residential, commercial and industrial applications.

Market Demand for Mass Timber Products

Glulam is a mature product with its earliest development patented in Germany in 1872. CLT is a much more recent development. It was first commercialised in Austria in the late 1990s as a joint industry-academia partnership.

Glulam has evolved to the point where it is manufactured extensively around the world. Global consumption of glulam in 2013 was around five million m^3/ year with Europe the largest market comprising ~ 2.7 million m^3/ year followed by Asia/Oceania ~2 million m^3/ year and North America ~0.3 million m^3/ year[8].

Annual global production has grown significantly over the past 10 years. Consumption of CLT in Europe has increased by over 600% to almost 500,000m^3 by 2012[9]. Global production of CLT is currently estimated to be around 700,000m^3/ year. In central and northern Europe it has gone from being a niche building material to a more standardised form of construction, which most builders and designers are familiar with[10]. Since 2012 CLT demand has continued to increase as production of CLT has expanded. Countries leading the use of CLT include Austria, Germany, Switzerland, Sweden, Norway and the UK.

CLT as a construction material has also gained popularity in North America since the late 2000s although production of CLT is still centred in Europe, from where it is shipped to clients around the world. CLT production has commenced in North America recently with the first manufacturing plants located in Canada.

CLT and glulam are increasingly being used across the globe as knowledge and familiarity with their use increases and markets recognise their unique characteristics. Glulam products are marketed as an alternative to steel for large beams or columns, or where strength bearing beams are part of the features of a building (such as exposed beams or stairs).

In the same way glulam is marketed as a substitute for steel framing, CLT is promoted as an alternative to building with slab concrete designs. Table 4-1 summarises the main factors that influence demand for CLT and glulam globally.

Table 4-1: Factors Influencing Demand for CLT and Glulam

Market Driver	**Comment**
Sustainability policies	Non-residential construction that stores carbon Minimal waste production Energy efficient building (CLT) Healthy indoor climate
Construction efficiency	Significantly reduced construction time Requires less staff Lighter than concrete Prefabrication and dry construction method Requires understanding of a revised planning process
Building performance	Earthquake resilience Fire safety Insulation properties reduce energy bills (CLT) Acoustic properties (CLT)
Market Driver	Comment
Construction barriers	Building codes (CLT) City planning systems Access to finance for innovative construction materials (CLT)

8 Forest Products Annual Market Review 2014-2015, Geneva Timber and Forest Study Paper 36, United Nations Economic Commission for Europe, eISBN 978-92-1-056875-3

9 http://www.woodworks.org/wp-content/uploads/2013-WSF-ATL-Collins.pdf

10 http://blogs.aecom.com/connectedcities/the-renaissance-of-timber-structures/

Market Driver	Comment
Awareness and perceptions	Skills to use required technology Perception of wood Consumer demand for high-rise residential buildings

Internationally, there are examples of different types of buildings having been constructed using CLT. The most notable have been high-rise residential and community buildings of differing sizes. In Europe alone more than 20,000 CLT projects have been completed[11]. Table 4-2 provides some notable examples of large scale CLT buildings.

Table 4-2: Example of CLT Projects Completed

Building	Size	CLT Volume	Construction Time	Special Benefits
Forté – Melbourne	10 storeys - 31.17m	~ 1 000 m^3 of timber, 759 CLT panels[12]	2012 (8 months)	
Library at the Dock – Melbourne [13]	3 storeys - 18m, 55m long	~ 574 m^3 of timber (Glulam beams: 140m^3)	2013 (2.5 months)	Lighter in weight required minimal alterations to the existing wharf structure.[14]
Stadthaus, Murray Grove – London, Hackney	9 storeys - 29.74m[15]	~ 926 m^3 of timber	2009 (7 weeks)	Carbon savings of 306 tonnes compared to steel and concrete building, and carbon capture of 181 tonnes in growing the trees resulted Hackney planners to waive London's requirement for 10% carbon reduction through on-site renewable energy generation.[16]
Birdport House – London, Hackney	8 storeys -	~ 1 576 m^3 1 100 CLT panels in 30 deliveries	2011 (3 months)	Overcame the weight restrictions of the site which sits above one of London's main drainage tunnels[17] The structure's height is double that of the building from 1950s it replaced, but the weight increased by only 10%.[18]
Dalston Lane – London, Hackney	10 storeys (9 CLT) - 33m	More than 3 000 m^3	Under construction	London borough Hackney's 'timber first' policy. 121 unit residential development.

Australia currently has two examples of CLT buildings. Both were constructed by Australian developer Lend Lease:

- The Forté apartment building in Melbourne comprises 10 storeys reaching to just above 32m, at the time the tallest CLT building in the world. The construction took just eight months to complete. The CLT panels were shipped from Austria to Australia with panel length limited to 12 metres due to container size; and
- The Library at the Dock is also located in Melbourne and was completed in 2013. It uses almost 600m^3 of CLT and glulam beams as large structural members. The material was partially chosen because it is lighter in weight than steel and concrete, which was important as the building is located on an existing wharf. The timber for Melbourne's library was produced at Stora Enso's CLT plant in Austria and shipped to Australia[19].

[11] http://www.woodworks.org/wp-content/uploads/2013-WSF-ATL-Collins.pdf
[12] http://www.woodworks.org/wp-content/uploads/2013-WSF-ATL-Collins.pdf
[13] http://www.melbourne.vic.gov.au/MelbourneLibraryService/Documents/CLT_Docklands_Library_factsheet.pdf
[14] http://www.architectureanddesign.com.au/features/product-in-focus/cross-laminated-timber-clt-australia-s-rising-star
[15] http://www.klhuk.com/media/8344/detail%2009nov2009.pdf
[16] http://www.klhuk.com/media/4532/murrayarchitectsjournal.pdf
[17] http://karakusevic-carson.com/work/bridport-house
[18] http://www.theguardian.com/sustainable-business/cross-laminated-timber-built-environment
[19] http://buildingandliving.storaenso.com/news/news-and-press-releases/stora-enso-clt-used-in-library-at-the-dock-australia%E2%80%99s-first-public-clt-building

The record of the 'highest CLT building in the world' has been broken several times in the past few years and will be broken again in 2016 – this time in an 'eco block' development in Québec, Canada. Canadian Nordic Structures is building a 13 storey residential building using CLT and glulam comprising some 7,800m^2 of floor space.[20]

No statistics are available on the global demand for CLT. However, the continued expansion in production indicates it is successfully finding a market niche and has been able to compete successfully against conventional construction techniques, particularly for low rise residential apartments. The recent successful CLT introduction in Canada indicates that a market penetration rate of up to 5% to 15% in certain market segments is possible[21].

Between 2000 and 2007 the global consumption of glulam more than doubled from 2 5 to over five million m^3/ year. Since 2007 subdued housing markets in the US and Europe have resulted in static consumption of around five million m^3/ year. Demand is once again increasing as housing markets improve in these key markets.

Construction Trends in Australia

A key driver of demand for wood products are the residential and non-residential construction sectors. The long term value of new residential construction and the alterations and additions market in Australia is shown in Figure 4-1.

Figure 4-2 shows the trend in dwelling commencements in Australia. The data showing approvals by building type (LHS) is split between detached housing and units which also include flats and apartments. Since 2010 the average annual number of new dwelling units commenced in Australia has been approximately 170,000[22]. Much of the recent growth has been driven by a sharp increase in multi-unit dwellings, particularly apartments.

In the short term, the Australian Constructors Association expects demand for multi-level apartment developments to increase by 14.9% in 2015, and 4.1% in 2016[23]. Much of this activity is expected to be concentrated in the major capital cities.

Building approvals are dominated by NSW and Victoria (Figure 4-2 RHS). Tasmania is one of the smallest markets in Australia averaging 2% of total commencements.

The non-residential construction sector comprises buildings such as offices, shops, hotels, industrial warehouses, hospitals, entertainment and represents another important potential source of demand, particularly for glulam.

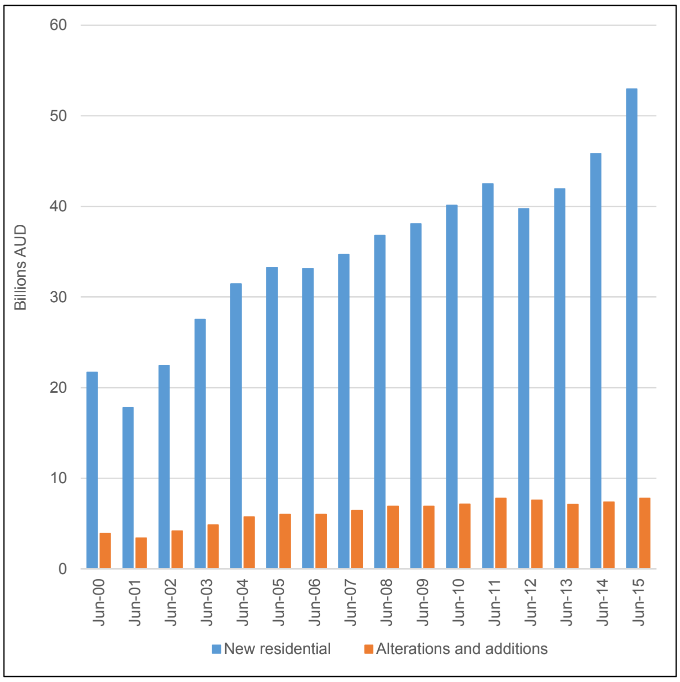
[20] http://ici.radio-canada.ca/regions/quebec/2015/02/24/006-tour-13-etages-structure-bois-pointe-aux-lievres.shtml

[21] FPInnovations (2011) "The Value Proposition for Cross-Laminated Timber", at http://www.fpac.ca/publications/Value-CLT-2011%20NABC%20anaylisfinal.pdf.

[22] ABS 2015

[23]http://www.constructors.com.au/publications/2015-05-26/construction%20outlook%20May%20Final%20REPORT.pdf

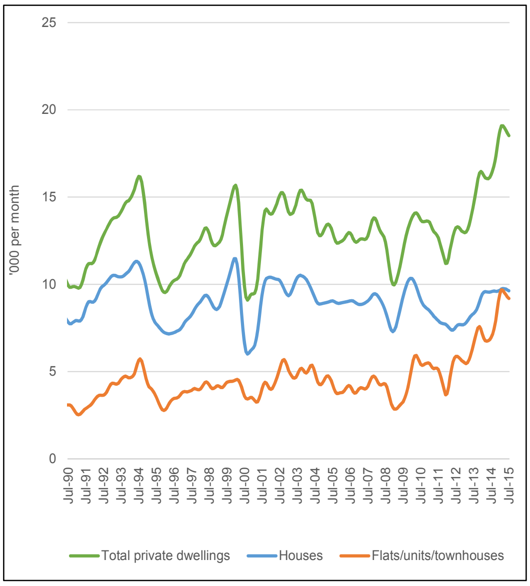
Figure 4-1: Value of Residential Construction Work in Australia



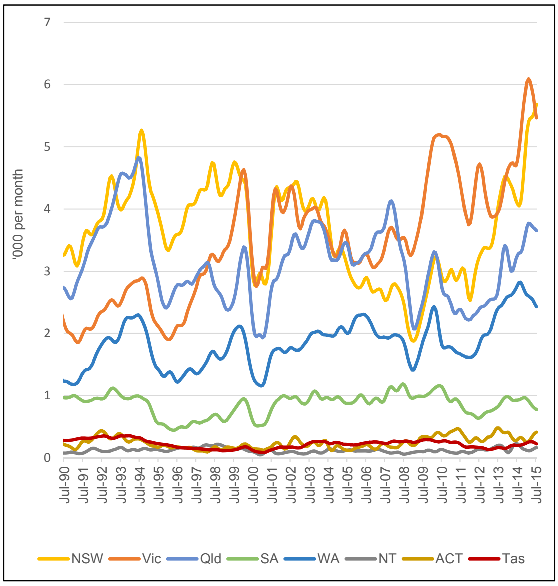
Source: ABS 2015

Figure 4-2: Annual Dwelling Commencement Trends in Australia

By Building Type



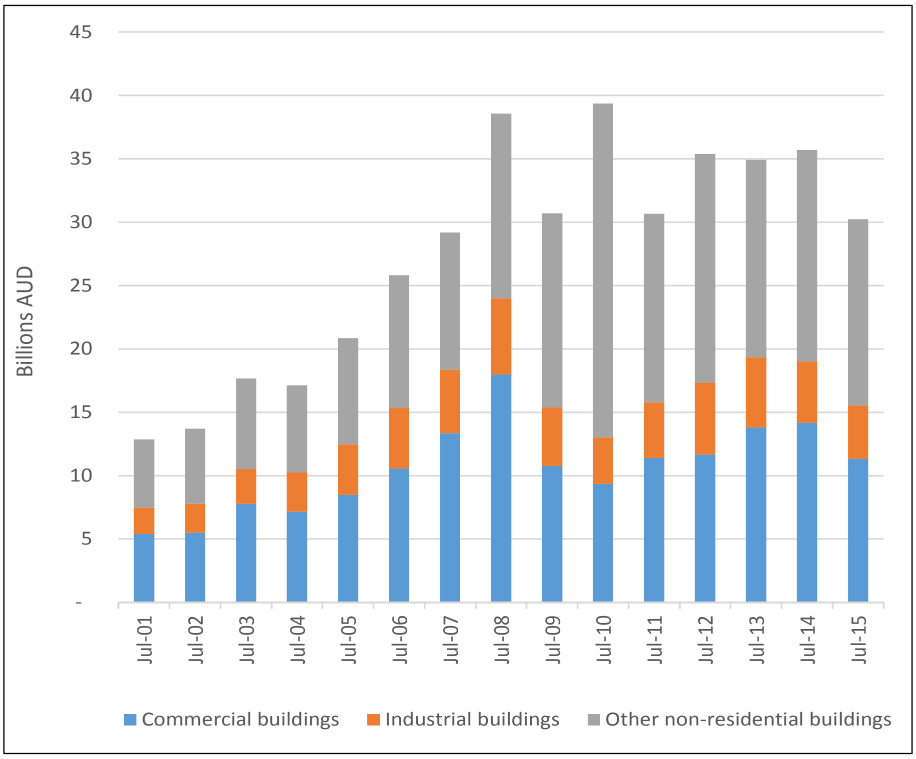
By State



Source: ABS 2015 (8731.0 - Building Approvals, Australia, July 2015)

Figure 4-3 shows the value of construction within the sector, highlighting the diversity of end markets where timber products could potentially be used. The 'other' non-residential building grouping relates to: education; religious; accommodation; recreation; aged care; and health buildings.

Figure 4-3: Annual Non-Residential Construction Trends in Australia



Source: ABS

The non-residential market grew substantially from 2001 to 2008, more than tripling in expenditure. Since the global financial crisis in 2009 the value of non-residential construction has remained relatively static.

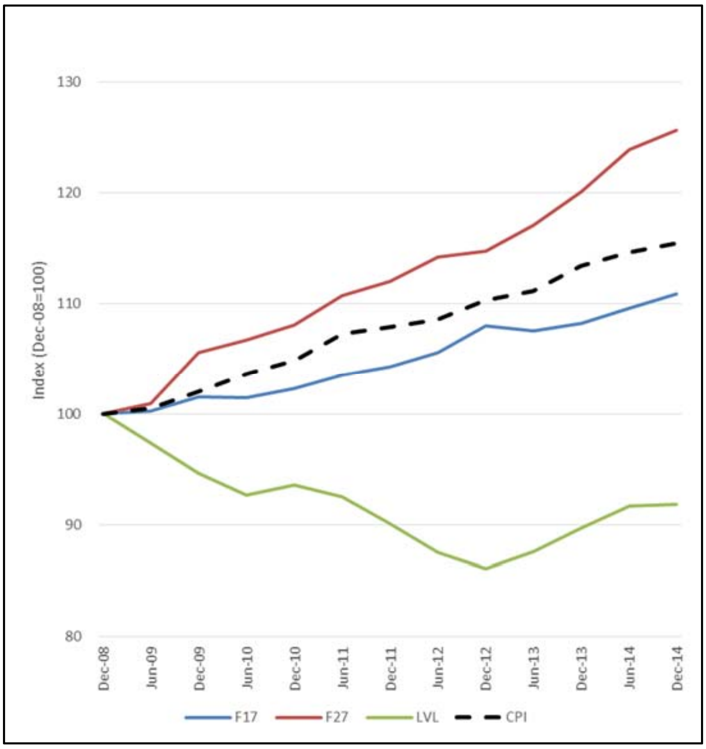
Price Trends in Structural Timber Markets

CLT pricing is typically negotiated on a bilateral basis between the purchaser and the wholesaler/manufacturer. As each CLT project is largely bespoke, variations in input requirements and design complexity can have a material impact on pricing. As a consequence there is little market information on CLT prices. In addition the price to the constructor reflects the timber production and the cost of design and panel manufacturing.

Glulam is used to produce a range of products and competes in a number of markets including the heavy structural construction sector. For timber products the F grading system defines the properties of the timber as defined in the Timber Structures Code. F grades represent a range of structural properties on a logarithmic scale, where the strength properties between grades increase with the F grade rating. It considers ratios between compressive, bending and tensile strengths based on a combination of visual and in-grade sampling. F17 and F27 are considered benchmark grades for heavy structural timber and would provide competition to glulam products.

In the absence of specific CLT or glulam pricing, Figure 4-4 shows a price index for key high strength timber products being F17, F27 and LVL. It shows prices for the greater strength structural F27 timbers have remained higher than for F17 grades and LVL. The LVL market has been in a state of oversupply for a number of years, with large volumes being imported from New Zealand and the US. This trend has also impacted on F17 timber prices where LVL has been able to compete. However, softwood LVL does not have sufficient strength to compete with F27 timber grades.

Figure 4-4: Price Trends for Heavy Structural Timber in Australia



Source: Timber Market Survey

In addition to large structural beams and columns, glulam products can also be used for a range of other smaller structural products including: chords, studs and sub-deck elements such as bearers and stringers. Hardwood glulam can also be used in appearance markets, such as stair treads and exposed lintels where the timber is exposed but a strength element is required.

Outlook for Mass Timber Product Demand in Australia

Australia's historic rate of population growth is around 1-2% per annum. The Australian Bureau of Statistics forecasts that by 2061 Australia's resident population will increase from a current population of 23.9 million to between 36.8 and 48.3 million people. Much of this growth is expected to occur along the eastern states with the population of Melbourne and Sydney each expected to exceed eight million people by 2061.

While there is a high degree of uncertainty around this forecast, population growth underpins demand for residential housing. Continued growth in Australia's major metropolitan centres would result in increased demand for more intensive housing to capitalise on existing and new investment in public transport infrastructure. Policies that promote more intensive housing are positive for potential CLT demand as many suburban apartment developments tend to be less than 10 storeys rather than high rise structures to better fit with their surroundings. An expanding market is also positive for glulam as it increases demand for alterations and additions. In this market glulam is well placed to offer a range of products.

This demand could be further enhanced through ‘wood first’ promotions. Recent examples include:

- **Australia** – ‘Wood is Good’ Generic multi-media promotion to encourage the use of wood as a construction material as well as a carbon sink;
- **Sweden**: local timber construction promotion strategy called “More wood in construction”[24] (“Mer trä i byggandet”) a national scale: timber construction promotion strategy; and
- **New Zealand - Rotorua District Council**: Promoting the use of wood as the first material of choice for construction, interior design and living developments within Rotorua.

A key barrier to the expansion of CLT as a building material are the limits placed on the use of timber for multi-storey buildings in the residential building codes. In many countries there are height restrictions for timber frame construction. Many of these restrictions were in force before the development of CLT. As its performance is now better understood, a number of countries (including Australia) have moved or are seeking to modify building codes to allow CLT to be used for multi-storey developments.

Lehmann *et al* (2012)[25] identified a range of other barriers to the rapid development of CLT:

- Cash flow inhibiting developers from engaging in innovative projects. Financial requirements for up to 50-60% of pre-sale commitments mean developers maintain existing building systems to ensure solid returns; and
- Costs associated with buildings four storeys and over discourage urban infill development, as they incur additional construction costs.

Ultimately the future of glulam in the Australian building industry will depend on the relative cost of the product to alternatives such as LVL, solid timber and other non-wood competitors, particularly steel. As consumers increasingly look to environmentally friendly products to fill structural building needs, glulam is likely to increase in use. For glulam demand to increase, customers will need to be aware of its merits and where it has a competitive advantage over other products. Currently it is a highly specialised product and will require greater market engagement from producers to expand market share against other heavy structural products. Its relatively small scale represents a barrier to broadening its use as only limited funds are available for promotion.

CLT is a relatively new product to Australia and beyond the two noted buildings in Melbourne, has had little use to date in detached housing. Because it is used in pre-fabricated housing, its uptake would require a change in product selection, building design and construction methods. Engagement by producers or importers with the commercial building industry (and potentially also government) to develop showcase buildings would help to secure greater interest.

An estimate for potential CLT penetration into the Australian building construction market is given in Table 4-3. Three estimations of potential CLT market size were undertaken – detached houses, residential units and non-residential (commercial/industrial) buildings. The estimates are based on the latest construction data and CLT yield factors used in the Scion and BRANZ assessment of CLT potential in New Zealand. The yield factors estimate the volume of CLT per square metre of building constructed.

The calculations show that a 1% to 5% penetration of the Australian housing construction market could consume between 70,000m^3 and 348,000m^3 of CLT/ year. Given a potential application for CLT is within the 5-10 storey building market, it is anticipated that parts of the unit dwelling sector would also be well suited for CLT uptake. Estimates of the same market penetration rates for this sector indicate a potential consumption of CLT between 38,260m^3 and 191,300m^3/ year.

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[24] http://www.forum-holzbau.ch/pdf/ihf09_Serrano.pdf

[25] Lehmann S, Reinschmidt A, Mustillo L (2012) Transition strategies: Accelerating social acceptance and removing the barriers to prefabricated multi-storey timber urban infill developments in Australia using CLT construction systems. Forest & Wood Products Australia Project No: PNE293-1213

The volume of CLT used in all residential construction assumes structures are built on a CLT-specific design.

Another significant potential market for CLT appears to be in the construction of non-residential buildings. Based on a penetration rate of 2.5% to 10%, the market is estimated to have the potential to consume between 91,000m^3 and 366,000m^3/ year using the SCION yield factors and between 107,000m^3 and 429,000m^3/ year using the BRANZ yield factors.

The combination of these results in a total potential market size for CLT in Australia of between 215,000m^3 and 968,000m^3/ year using the BRANZ conversion factors and the market penetration assumptions.

The timing of CLT uptake into the market is not taken into account. As these estimates use a wide range of assumptions the results should be treated with caution.

Table 4-3: CLT Consumption Potential for the Australian Building Market

Construction Type	Assumed Penetration Rate	Estimate using SCION Yield Factor	Estimated using BRANZ Yield Factor
Detached houses	1%-5%	Not provided	70 000 m^3 to 348 000 m^3
Other residential buildings	1%-5%	38 260 m^3 to 191 300 m^3	38 260 m^3 to 191 300 m^3
Total Residential	**1%-5%**	**38 260 m^3 to 191 300 m^3**	**108 000 m^3 to 539 000 m^3**
Non-residential	2.5%-10%	91 000 m^3 to 366 000 m^3	107 000 m^3 to 429 000 m^3
Total		**129 260 m^3 to 457 300 m^3**	**215 000 m^3 to 968 000 m^3**

4.3 Technology and Proponents for Production of Mass Timber Products

Glulam

Glulam is a secondary manufacturing process where short lengths of wood are finger jointed and glued together to produce a range of multi-dimensional products. Lamination lengths can be as long as six metres or as short as 400mm. Longer lengths generally provide greater strength as finger joints are inherently weaker than knot free solid wood. Different combinations of timber length are used depending on the final strength characteristics needed in the end product.

An important feature of glulam is that it can be bent to produce curved shapes, thereby having the capacity to provide a more aesthetically attractive shape to conventional steel and concrete construction, as well as potential uses in bridges and roof spans.

Glulam facilities are typically (but not always) co-located with a sawmill to increase the utilisation of lengths that are generally too short to meet traditional timber market requirements.

Glulam is produced in Australia by several companies with two of the largest being:

- Hyne Timber in Queensland - produces glulam from softwood timber, produced at its Tuan mill which has an annual log intake of approximately 700-800 000m^3/year; and
- Australian Sustainable Hardwoods (ASH) in Victoria – uses approximately 50 000 m^3/year of ash sawlogs sourced from native forests.

Both glulam facilities are co-located with their sawmilling operations and use the glulam line as an important value-add to their overall operations.

Cross Laminated Timber

CLT is also a secondary manufacturing process that joins lengths of timber into large dimension panels. Each panel is joined at right angles to the adjacent layer with the face and back layers having a vertical orientation. Core layers can have a horizontal and/or vertical orientation depending on the number of layers (typically three through to seven layers) in the panel. Alternating the grain direction reduces weaknesses present within any single layer.

CLT's advantages are that it can be manufactured to exact dimensions as a pre-fabricated panellised construction material. As a result the wooden panels can be screwed into place easily resulting in a significant reduction in construction time. Furthermore the panels also provide the internal walls providing interior decorating options similar to existing wall surface products. Like other wood products, CLT also has strong environmental attributes and is highly portable relative to non-wood alternatives. These factors have all helped to bolster its initial success as a building product in the European market.

CLT is not currently produced in Australia but has been imported as made-to-order panels from European manufacturers that use softwood timber feedstock. Most CLT production occurs in Austria and Germany centred near the product's largest sources of demand. Table 4-4 shows some of the major producers of CLT and key end markets, being largely Europe and North America.

Table 4-4: Major Manufacturers and End Markets for CLT

	End Markets			
Producer	**Europe**	**North America**	**Asia**	**Australia**
KLH	x		Taiwan	
Stora Enso Building & Living	x	x		x
Smartlam		x		
Nordic Structures	x	x		
Structurlam		x	Taiwan	

KLH opened its production facility in Austria in 1999. The company employs 130 people and produces approximately 650,000m^2 (~98,000m^3 pa assuming 0.15m^3 of timber per m^2 of CLT) of CLT annually. KLH has a subsidiary in the UK and distribution partners all over Europe, Canada, Taiwan and Turkey.[26]

Finnish sawmiller Stora Enso has two CLT production facilities in Austria, with the second constructed in 2011. The new facility cost EUR23 million to build, employs 59 people and has an annual production capacity of 63,500m^3. The expansion is supported by growth of European CLT market over the last decade. Stora Enso distributes globally with sales offices in Finland, Austria, Germany, UK, France and Australia.

Nordic Structures, via its subsidiary Chantiers Chibougamau, recently expanded its factory to a capacity to produce 80,000m^3 of CLT annually. An investment of around CA$10 million was required, taking advantage of existing equipment. The company was motivated by the European market where the ecological footprint, security, energy performance and acoustics of buildings are more highly valued than in Canada. The project created an additional 35 jobs in Québec.

Structurlam started producing CLT in 2010 establishing its first CLT plant in Okanagan Falls, British Columbia using CA$5 million of government funding and CA$7.5 of private funding[27]. In 2013, the plant was expanded by 10,000 square feet at a cost of around CA$7 million which included a panel-cutting robot at a cost of CA$1.5 million[28]. Structurlam currently has three production facilities where glulam and CLT is manufactured.

Xlam is the sole producer of CLT in Australasia. The company's CLT plant is located in Nelson, New Zealand and primarily uses sawn radiata pine as a feedstock. The company was able to utilise the Christchurch reconstruction effort as a platform for growth. The combination of CLT's good seismic performance; rapid construction and low rise nature of the Christchurch CBD

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[26] Company website: http://www.klh.at/en/company/facts.html

[27] http://www.pentictonwesternnews.com/news/118038149.html

[28] http://www.pentictonherald.ca/news/local_news/article_1afe3a60-bbf8-5d02-a67e-039ceeebc7d1.html

made it well suited to this market. Xlam is seeking to double its capacity, and is investigating the potential of opening an Australian facility.

There is currently no CLT produced from hardwood timber. The North American Hardwood Association is investigating the commercial opportunities for hardwood CLT and is looking to develop a business case. However, it has identified that hardwood CLT doesn't have the same weight to strength advantage as softwood, which may mean price would become a driver of demand for hardwood CLT.

4.4 Social and Environmental Considerations

Environment

Both glulam and CLT are secondary manufacturing processes that use sawn timber as a feedstock. Losses are limited to re-design and making the finished product fit for purpose, rather than substantial losses that occur during the manufacturing process. These two products combined currently utilise relatively small volumes with most supply coming from within the existing wood processing supply chain. Therefore their impact on demand for additional logs would most likely be negligible.

Timber has a lower carbon footprint than other construction materials such as steel and concrete. For example, when the sequestered carbon locked up in Bridport House, a 1,576m³ timber structure, is added to the carbon avoided through the use of CLT, an estimated total of 2,113 tonnes of carbon is either stored or not emitted[25].

The resin contained in glulam and CLT may contain formaldehyde however like plywood and LVL there is a relatively small percentage of resin by weight, due to the high proportion of wood in these products. New high-pressure bonding systems allow the use of polyurethane adhesive in the boards. This solvent and formaldehyde-free adhesive achieves a high quality level of adhesion, with no toxic emissions during the product's life cycle.

Modern dust extraction and management system can limit the concentration VOC emissions at the production site and this is regulated by Worksafe Australia.

A glulam or CLT plant would generate a relatively small amount of noise and road congestion. The small production space would also mean that dust and particulate emissions would be minimal.

Social

A CLT or glulam operation would directly employ around 10-50 people, depending on the scale of production.

4.5 Prospects for Mass Timber Production in Tasmania

CLT and glulam represent a market opportunity for Tasmanian residues because:

- They provide the potential to utilise timber within the existing supply chain that would otherwise be chipped or diverted into low value markets;
- These products can displace energy intensive construction materials such as steel and concrete with a more environmentally sustainable product; and
- It has the potential to support the viability of the hardwood sawmilling sector. The inclusion of a secondary CLT/ glulam plant allows for a greater utilisation of low grade timber.

End Markets and Feedstock Availability

Both CLT and glulam have the potential to expand the Australian timber industry. They represent a modern manufacturing approach where it is necessary to do more with less as well as minimising building site labour and construction times. However, Tasmania currently has limited demand for either CLT or glulam, and neither product is produced in the state. Similarly there is limited existing expertise in the Tasmanian construction sector on the utilisation of these materials.

A typical CLT or glulam operation could be as small as 5,000m^3/ year or up to 50,000m^3/ year depending of the size of the market opportunity and the investment characteristics of the operation. Both CLT and glulam rely on a steady supply of sawn timber and on a small scale are ideally run in cooperation or coordination with a sawmilling operation.

There is sufficient softwood processing capacity in the state to be able to establish a CLT or glulam plant. It is likely that the bulk of the feedstock would be sourced from the existing timber produced by the mill. Most of the processing residue produced is unlikely to be of a merchantable size for processing into CLT or glulam. Based on interviews with the state's hardwood sawmilling sector the NCFFI notes industry reported processing around 150,000m^3 of hardwood log to produce around 55,700m^3 of high-value appearance board in 2013/14.

The feedstock for a glulam/ CLT plant would comprise a combination of:

- Low value timber currently utilised as either as short lengths or industrial grade. These timber grades are not classified as residues but typically comprise around 10-25% of total timber production; and
- The residue component that may provide a feedstock to a glulam/ CLT plant would be short timber lengths that may currently be chipped (especially for glulam) where these pieces are greater than 400mm and may be finger-jointed together.

The NCFFI reports approximately 61% of primary hardwood sawmill residues are generated as irregular solid timber sections such as wing boards, heart and similar material. As logs are processed into boards through the green mill this timber ends is converted into green woodchips and green waste wood. It is estimated a total volume of 70,000m^3 of this material is produced annually.

No data is available on the size distribution of this material, but the dimensions of the boards are likely to be much more variable than for a softwood mill. Therefore it may be possible that a small proportion of these residues could be processed and converted into a feedstock as part of a glulam/ CLT operation. A 10% recovery would equate to a state wide supply of around 7,000m^3/ year.

The hardwood sawmilling sector is highly dispersed across Tasmania. Regional studies by PFT investigating biomass availability in the Huon and Dorset regions identified the location of processing facilities in each region. The report identified 13 hardwood sawmills in the Huon (SE) region and 22 hardwood mills in the Dorset (NE) region. The log supply to each of these mills is not identified, but the number of mills suggests the annual intake for each mill is relatively small. This means the relatively small volume of suitable residues produced by these mills will also be geographically dispersed.

Subject to confirmation of suitability as a feedstock, timber from hardwood plantation logs could also be utilised. However, the feasibility of utilising this material has yet to be proven. Larger diameter plantation logs would be a preferred source, but some smaller plantation logs, currently classified as pulpwood may also produce acceptable sawn timber, particularly if defects such as knots can be cut from the timber.

Economic Considerations

Insufficient price data is available to assess the economic fundamentals of establishing a CLT facility in Tasmania. The establishment of CLT plants overseas indicates a capital cost in the vicinity of AUD12-36 million depending on scale.

A New Zealand study on the potential for CLT using radiata pine by SCION found CLT performed well in relative to other wood products. Financial modelling for a 30,000m^3/ year plant indicated a potential return on capital of around 12%. The result showed the return was very sensitive to pricing, which given CLT is a developing market represents a substantial market risk factor. Glulam technology showed a slightly better return on capital of 13%, but the report notes it assumes a relatively small input volume of 9,000m^3/ year[29].

A study commissioned by the Forest and Wood Products Association of Australia investigated the cost of timber construction for four different building types compared to other construction methods. Each building type was designed then independently costed. The analysis considered only the elements where there were significant differences and ignored cost elements that were the same irrespective of construction method. Cost inputs such as mechanical, electrical, plumbing, floor coverings, car parking levels and fit out were excluded[30]. Table 4-5 presents the results from the costing analysis.

Table 4-5: Cost Comparison for Various Building Types and Construction Methods

Building Type	Timber Type	Timber Cost ($ million)	Alternative Type	Alt. Cost ($ million)	Timber Cost Saving (%)
7 storey office	LVL	6.4	Concrete	7.3	12.4%
8 storey apartment	CLT	5.0	Concrete	5.1	2.2%
2 storey aged care facility	Timber frame	0.7	Steel frame	0.8	13.9%
Single storey industrial shed	Glulam frame	0.22	Steel frame	0.24	9.4%

Source: FWPA

In all of the examples examined, the timber construction method had a lower cost than the alternative non-timber building with savings ranging from 2.2% to 13.9%. This suggests it is possible for timber to compete with these other construction methods on a cost basis.

Pathway for Residue Utilisation

Demand for CLT and to a lesser extent glulam are expected to expand as construction methods for using these materials becomes more widespread. In some countries this is being promoted through government policies specifying timber construction. Demand could also arise due to savings in construction time, and in consumer preferences regarding the feel of timber buildings.

Non-timber construction methods are relatively well known, have been applied many times and have a well-developed supply chain. As a consequence there is limited scope to reduce their costs further. In contrast, timber design is already competitive with these methods, but the systems, especially the use of CLT, is not well understood and has the potential to realise further savings through the supply chain.

Tasmania has a relatively small construction market compared to other states in Australia. However, there are local developments such as the Macquarie Point redevelopment which provide an opportunity to showcase the use of timber and stimulate demand. Sustaining a project pipeline based on the Tasmanian market alone would be challenging.

While a CLT or glulam facility in Tasmania would have a low capital cost relative to other options there are several critical supply chain issues that would need to be overcome for any development to be commercially viable:

- The establishment of a hardwood glulam or CLT plant at the larger end of the scale spectrum would most likely require supply from multiple mills. Any double handling of timber incurs additional costs that reduce the competitiveness of the end product. By comparison the ASH facility in Heyfield Victoria has a log input of approximately 50,000m^3/ year and produces glulam from timber produced inside the gate;
- CLT production to date is based on softwood timber. A hardwood CLT production process would need to prove up the additional benefits of hardwood while mitigating the additional

[29] SCION (2013) Cross Laminated Timber Potential in New Zealand

[30] Timber Development Association (NSW) Ltd (2015) Final Report for Commercial Building Costing Cases Studies – Traditional Design versus Timber Project. Forest & Wood Products Australia Project No: PN308-1213

weight of such a product. Such a proving up process may be difficult given a key benefit of softwood CLT is its ease of use in balancing weight, strength and construction simplicity;

- CLT production from differing timber species also requires proving up to confirm the suitability and performance of each species. This exercise incurs cost and time, particularly in gaining confidence from the end users; and
- For both hardwood and softwood products, distribution of product outside of Tasmania is faced with the same shipping limitations other importers to Australia face, namely the capacity to transport oversize materials. Other importers of CLT have developed their product specifically to fit within shipping containers. The establishment of CLT or glulam facilities in the other Australian states means that larger dimension material could be produced without this barrier.

A small scale plant is a more prospective option, particularly for a hardwood sawmill, but this would be a niche operation and have limited impact on residue volumes. Hardwood glulam has the potential to be used for appearance purposes, which would increase its exposure to the alteration and additions market in addition to structural markets. This provides a differentiator from other softwood glulam products. The development of a small pilot scale operation, with a view to scaling up may be the best approach for greenfield investors.

Table 4-6 provides a summary of the key considerations for further development of the engineered wood product sector.

Table 4-6: Summary of Key Considerations for Mass Timber Development in Tasmania

Criteria	Key Considerations
Key Success Factors	Existing feedstock of low value timber that could potentially be utilised as a feedstock
Key Challenges	Market development required for a CLT/ glulam products, including technical product testing and market acceptance of potentially heavier product Building standards especially for the use of CLT
Barriers to Entry	Securing sufficient supply at an economical cost, especially if double handling of timber is required Building standards –Australian Standards don't currently reflect capacity to develop multi-storey building as a right using timber, but these are in the process of being updated
Collaborators	Commercial property developers, builders, designers and architects in residential and non-residential markets Domestic sawmillers International equipment suppliers
Competitors	Existing CLT/ glulam producers and importers Steel and concrete producers
Policy Considerations	Consider the impact associated with a wood first policy
Potential Timeframes for Further Development	No physical or technical barriers to the development of a glulam or softwood CLT facility R&D required to investigate feasibility of producing hardwood CLT and its performance compared to softwood CLT

5. STAND-ALONE BIOENERGY

5.1 Option Summary

Tasmania has a mature electricity market with a number of different energy options available for electricity generation with hydroelectric power being the largest source. In recent years, Tasmania has been a net exporter of electricity via the Basslink cable to mainland Australia.

Electricity demand in Tasmania is expected to remain static with energy intensive industries at a mature rather than expansionary phase. Energy efficiency initiatives and developments in other renewable technologies such as rooftop solar are also impacting on demand for electricity from the grid.

The Renewable Energy Target (RET) is a longstanding federal government program that supports and promotes renewable energy via incentives for the generation of electricity from eligible renewable sources. Electricity from wood currently supplies only around 1% of the eligible generation under the RET, and has not changed significantly over a ten year period.

Electricity generation from biomass can use a number of different technology pathways, all of which are mature with known costs. Many technologies have the capacity to process a wide range of biomass types, including woody biomass. This indicates major technology enhancements beyond existing performance is unlikely to occur.

Electricity from woody biomass is almost always produced via mature combustion technology. As such environmental compliance is well understood and bioenergy plants are capable of routinely meeting EPA requirements for emissions.

The estimated cost to produce electricity from biomass currently exceeds the wholesale electricity price even when: Large-scale Generation Certificates are taken into account; the biomass facility scale is maximised; and feedstock is sourced at effectively a zero cost. Without increases to the electricity price or explicit government support, bioenergy generated electricity is only competitive to particular electricity consumers or circumstances.

The most prospective development for stand-alone bioenergy in Tasmania is as a cost effective alternative to enhancement of the electricity transmission or distribution infrastructure in the future. No such opportunities were identified during the study.

5.2 Markets for Stationary Electricity Generation

Figure 5-1 shows Tasmania's energy flows from supply source to end use sector. Total energy supply in Tasmania in 2012-13 was approximately 112 petajoules (PJ[31]). The relative contribution from each source and its respective end use is indicated by the thickness of the line[32].

The industrial sector has the highest level of energy use in Tasmania with electricity being the dominant source of supply. This reflects the establishment of energy intensive industries such as aluminium, manganese and zinc smelting, paper and cement manufacturing during the period of expansion in hydroelectric power generation in Tasmania. Collectively five major industrial facilities account for more than half of Tasmania's total electricity consumption.

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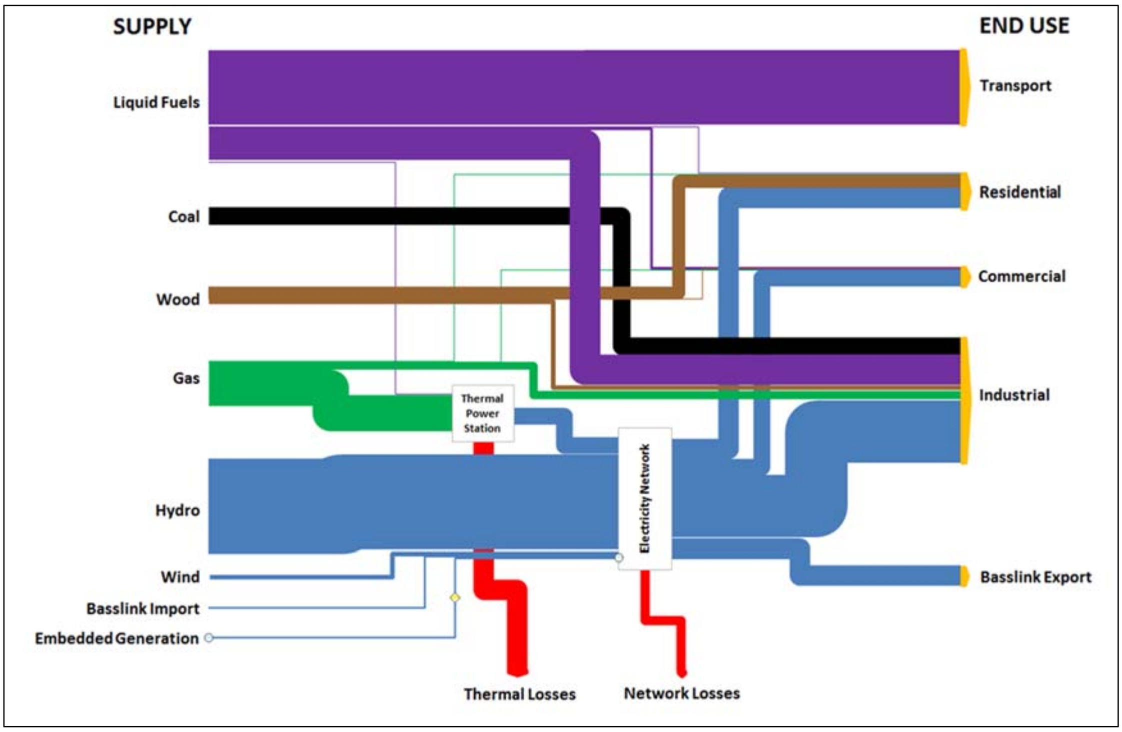
[31] One petajoule has the equivalent energy to 163 400 barrels of oil. Tasmania's annual energy demand is equivalent to approximately 18 million barrels of oil per year.

[32] Office of the Tasmanian Economic Regulator (2015) Energy in Tasmania – Performance Report 2013–14, ISBN 978-0-7246-5354-6

Liquid fuels represent the next largest source of energy supply in Tasmania and is discussed in more detail in Section 7. Coal is a relatively minor source of energy as is wood, which is largely utilised as firewood for home heating.

Figure 5-1: Tasmanian Energy Flows 2012/13



Source: Office of the Tasmanian Economic Regulator

Hydroelectric power accounts for around 76 per cent of Tasmania's installed generation capacity. The level of hydroelectricity generation varies from year to year depending on water storage levels. Figure 5-2 shows the relationship between water storage levels and the level of electricity generated. During 2013/14, Hydro Tasmania generated approximately 86% of Tasmania's electricity compared to 81% in 2012/13.

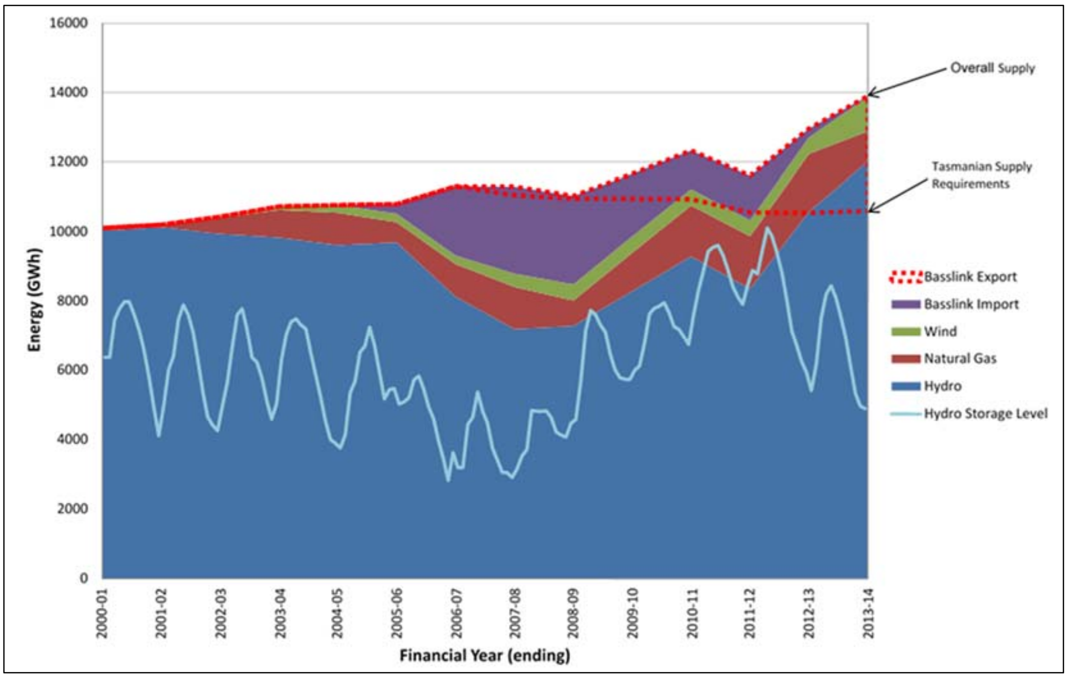
Another feature of the Tasmanian electricity network is its connection to the National Electricity Market (NEM) of eastern Australia via the Basslink cable. The cable allows power generated in Tasmania to be exported into the NEM and conversely for power to be imported into Tasmania thus limiting exposure to shortfalls in generation capacity.

Depending on load requirements and water storage levels, Tasmania can be a net importer or exporter of energy over the course of a year. During the 2006-2009 drought over 1,900GWh/year was imported with imports peaking at 2,635GWh in 2008/09. In recent years Tasmania has been a net exporter sending 2,500 and 3,000GWh to the NEM during 2012/13 and 2013/14 respectively.

Hydro Tasmania also owns the gas powered Tamar Valley Power Station at Bell Bay. The power station provides back-up generation capacity and only runs intermittently.

Prior to 2013/14 wind generation accounted for around 500 GWh of generation capacity. This increased to around 1,000GWh with the commissioning of the Musselroe wind farm in 2013.

Figure 5-2: Tasmanian Electricity Supply by Source



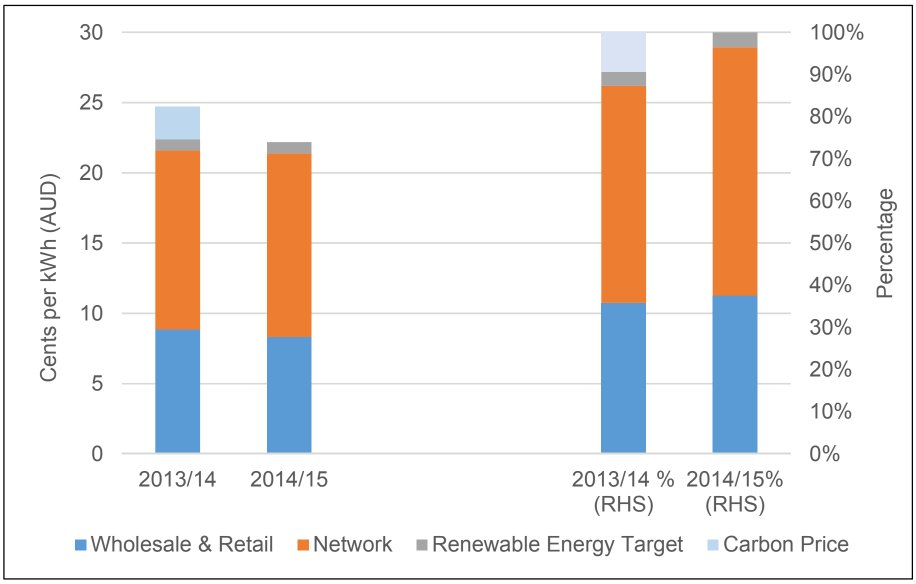
Source: Department of State Growth

There are three main components in the electricity supply chain:

- **Wholesale electricity** - the generation of electricity at grid-connected power plants;
- **Network services** - which includes transmission (moving energy in high volumes from the source(s) toward end users) and distribution (supplying and metering energy to end users' premises); and
- **Retail services** - billing and managing price risk for end users.

Each of these components may be undertaken by separate businesses. Figure 5-3 shows the extent to which each of these components contribute to the overall retail cost of electricity.

Figure 5-3: Composition of Retail Electricity Costs in Tasmania



Source: Australian Energy Market Commission

Approximately 59% of the retail electricity cost (excluding any carbon costs) is related to the transmission and distribution network. Wholesale and retail costs are the next largest component accounting for 37% of the total cost. The cost associated with meeting the Renewable Energy Target (RET) makes up the remaining 4%.

Status of Renewable Electricity Markets in Australia

The RET is a long standing federal government program that supports and promotes renewable energy via incentives for the generation of electricity from eligible renewable sources. The creation of renewable energy certificates creates the 'supply' side of the market. The Renewable Energy (Electricity) Act 2000 requires liable entities (mainly electricity retailers) to source renewable energy certificates. This creates the 'demand' side of the market.

Following a government review[33] a national RET of 33,000 MWh/year was set in May 2015 for electricity generation by 2020 from eligible large scale renewable generators. Approximately half the necessary generating capacity to meet this target is already in place. More than 80% of existing eligible generation is provided by wind and hydroelectricity.

Bioenergy currently contributes approximately 10% of the generation[34]. Within the bioenergy category the majority of electricity is generated using landfill gas and sugar cane residues[35]. Woody residues contribute approximately 10% to the total bioenergy amount, indicating that electricity from wood currently supplies around 1% of the eligible generation under the RET. This proportion has not changed significantly over a ten year period.

Woody biomass has been an eligible renewable energy source since the original version of the scheme was put in place more than ten years ago. However the definition of woody biomass was changed in 2011 to exclude material sourced directly from native forests. This was revised in 2015 to make native forest residues eligible for Large-scale Generation Certificates (LGC).

The price paid for LGCs is variable and influenced by supply and demand at any time. LGCs may be contracted to a particular customer in bulk at the start of development of a renewable energy project. They may also be held by the project developer/operator and sold on the spot market. Spot market prices in particular may vary with supply and demand. LGC spot pricing between January and August 2015 has increased from under $35 to approximately $55 per LGC. The “ceiling“ price for LGCs is influenced by the Renewable Energy Act, which assigns a penalty of $65 (plus any applicable taxes) per LGC for any shortfall in LGCs from a liable entity.

Outlook for Energy Demand in Tasmania

TasNetworks Corporate Plan forecasts annual growth in Tasmania’s electricity demand of 0.8%/year. This reflects the mature nature of Tasmania’s energy intensive industries. Other factors such as energy efficiency improvements across the industrial and residential sector and the ongoing expansion of rooftop solar are also expected to slow the rate of electricity demand from the grid.

The 2014 National Transmission Network Development Plan found there was no expectation of a need for additional capacity in the Tasmanian transmission network for the next five years.

5.3 Technology and Proponents for Bioenergy Production

The most common technology for generating electricity from biomass is to use a combustion system to raise steam, which is expanded in a turbine that drives a generator to produce electricity. The process is similar to the combustion of coal in coal-fired power stations. While

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33 http://www.cleanenergycouncil.org.au/policy-advocacy/renewable-energy-target/A-bipartisan-renewable-energy-target.html

34 Rathore A – Opportunities for the waste industry. Presentation at Bioenergy Australia national conference, December 2014

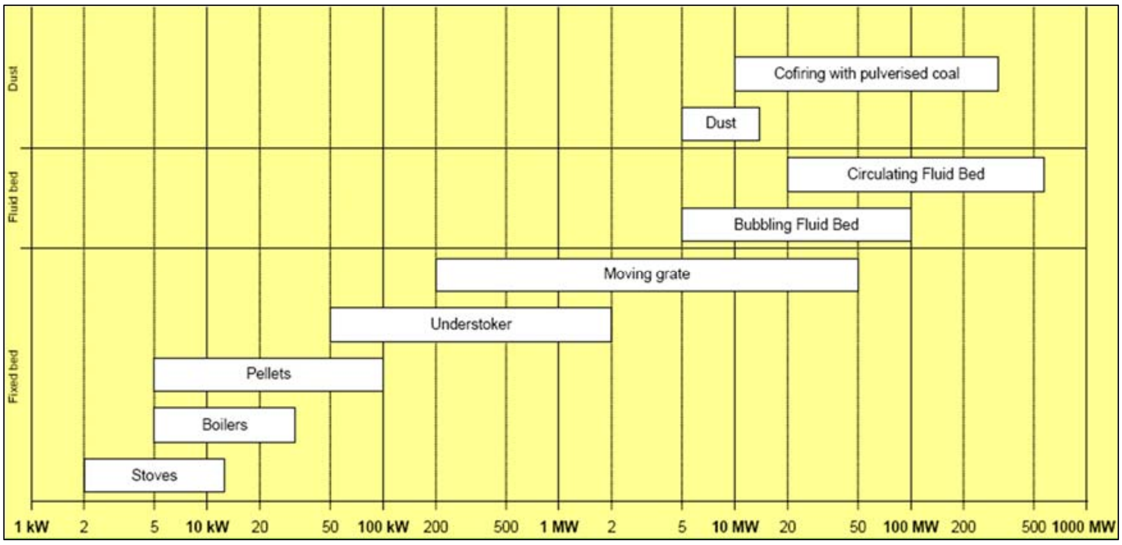
35 Stucley C *et al* – Figure 1-6, Bioenergy in Australia – status and opportunities - http://www.bioenergyaustralia.org/

the production of steam using heat from the combustion of biomass is efficient, the conversion of steam to electricity (via the Rankine cycle) is much less so. Approximately 90% of the world's large-scale bioenergy plants operate through combustion processes.

Biomass combustion systems can be very efficient at producing hot gases, hot air, hot water or steam, typically recovering 65-95% of the energy contained in the fuel. Lower efficiencies are generally associated with wetter fuels.

Combustion systems can range in size from 2 kW for small combustion stoves to in excess of 500MW electrical output using a circulating fluidised bed system. The smaller systems tend to have 'fixed beds' which contain the combusting biomass, while the larger systems tend to be of the fluid bed or dust firing variety. Figure 5-4 shows the relationship between the type of combustion system and the scale of the energy output.

Figure 5-4: Scale of Bioenergy Combustion Systems



Source: Enecon

Combustion technology has been developed over many decades and is mature relative to some other bioenergy technologies. This is a beneficial attribute for raising capital, as the reliability of the technology has generally been demonstrated elsewhere. On the other hand it means that significant breakthroughs with new technology and greater efficiency or lower capital costs are unlikely.

While production of electricity from biomass reached 93,000MW of total installed capacity globally in 2014 there is no dedicated wood to electricity capacity in Australia. All of the biomass to electricity plants established to date in Australia are based on cogeneration where process heat is produced in addition to electricity.

As Figure 5-4 demonstrates, the technology and scale of combustion systems vary considerably. Examples range from the small scale gasifiers, generally established in developing countries that lack an established transmission network through to dedicated, large-scale plants that provide economies of scale. An example of the latter is the 37.5MWe power plant in Plainfield Connecticut, shown in Figure 5-5.

Figure 5-5: Example of a Bioenergy Plant Developed for Electricity Generation

Source: Enecon

The footprint for this plant is apparent from the photograph and the overall site covers approximately 12 hectares including buffer zones. Power plants can vary in scale from larger than this example to less than 1MWe, and the footprint of the plant will vary accordingly.

Suppliers for these plants range from those who provide individual items of equipment through to major contractors that offer turnkey contracts for the design, supply and installation of complete power plants.

5.4 Social and Environmental Considerations

Environment

Bioenergy is used globally for renewable energy because the carbon dioxide released is matched by carbon dioxide captured from the atmosphere via the photosynthesis that drives plant growth and creates the biomass that will go into the bioenergy plant.

The main products of efficient biomass combustion are carbon dioxide and water vapour, however tars, smoke and alkaline ash particles may also be produced. A range of gas cleaning technologies are incorporated into biomass combustion plants to achieve environmentally acceptable emissions.

Combustion creates flue gas, which is made up of the gaseous products of combustion plus entrained particulate matter. Nitrogen oxides (NOx) are also produced and limits may be set for their discharge. NOx reduction can be achieved by modifying the combustion process.

As a mature technology environmental compliance is well understood and bioenergy plants are capable of routinely meeting EPA requirements for emissions.

Social

The combustion of biomass for energy could potentially include feedstock sourced directly from native forests. Until recently this was hindered because such biomass was not defined as an eligible fuel source for the generation of LGCs, which are a major source of revenue for renewable electricity projects. This situation has recently been revised so that residues sourced from native forests are eligible for the generation of LGCs. However, any use of these residues would require careful consideration and widespread consultation to demonstrate there were minimal environmental impacts associated with their utilisation. Biomass energy production from native forests would need align with existing forest management plans.

The amount of feedstock required for any of the plants described in this section is well within existing residue production levels in Tasmania and would be unlikely to lead to any intensification of harvesting activity. Rather the use of residues would improve the overall utilisation of the fibre generated from harvesting within these forests, thereby reducing fuel loads and subsequent risk of intense wildfires.

The level of employment depends on the scale of the combustion operation. Small plants will have a relatively low labour requirement, whereas large stand-alone facilities will require significant labour inputs.

5.5 Prospects for Stand-alone Bioenergy in Tasmania

Stand-alone power generation would utilise biomass to generate electricity which is fed directly into the electricity grid. It is important to take grid infrastructure into account when selecting a location and size for a bioenergy plant. From time to time the electricity grid is modified so it can meet the changing needs of electricity customers. If capacity has been reached in a particular part of the grid, increased electricity demand in that area may need to be met via the installation of additional capacity for transmission and/or distribution, possibly coupled with upgrades to substations and other infrastructure.

Such changes to the grid come with associated capital costs. As an alternative to an upgrade of the grid, it may be possible to meet increased electricity demand via supply from new electricity generators located strategically within the grid to provide more localised electricity. Under some circumstances, this new source of supply may be more cost-effective than an upgrade to the grid itself.

TasNetworks were contacted during the preparation of this report and advised that there were no capital works planned for the grid where new electricity generation capacity could play an alternative role [36]. It would therefore appear that at present there is no justification for considering electricity generation from biomass as a component of grid improvement in Tasmania.

Economic Considerations

In the absence of a specific project that can be used as a case study for electricity generation from biomass, an analysis was competed investigating the economics of establishing various sized bioenergy facilities. The analysis is reproduced from a previous report by the co-authors, published in 2012 titled "*Bioenergy in Australia – Status and Opportunities*". The data presented has not changed significantly from the original data developed for the first publication of the report in 2004. This is largely because the combustion technologies involved are mature and not expected to vary significantly over time.

Key determinants for the cost of electricity from a biomass plant are:

- The scale of the plant;
- Biomass fuel costs; and
- Maximising the running time of the power plant.

The three hypothetical bioenergy plants assessed are: a 500kW gasification plant (based on automated European equipment) fuelling a reciprocating gas engine that drives a generator, a 5MW and a 20MW plant using conventional boilers and steam turbines to produce electricity. An assessment of the feedstock requirements, capital costs and operating costs per year is summarised in Table 5-1.

[36] Personal communication, Cameron Thomas – Manager Planning at TasNetworks

Table 5-1: Assessment of Annual Costs for Various Sized Bioenergy Plants

Input/ Output	500 kW	5 MW	20 MW
Gross electrical output (MWe)	0.55	5.5	21.5
Feedstock requirements (green tonnes/year)[37]	9 000	79 000	280 000
Overall efficiency (gross output per tonne of green feed assuming 10 GJ/tonne)	18%	20%	22%
Capital cost ($ million)	$4	$27	$63
Operation & maintenance cost ($million/year)	$0.22	$1.6	$3.4
Unit capital cost ($million/MW)	8.4	5.4	3.1

Source: Enecon

This table illustrates the benefits associated with economies of scale, with the per-megawatt capital cost for a 20MW plant only 40% of the cost for a 0.5 MW plant. Smaller plants generally have a proportionately higher fixed development cost.

A simple costing model was developed to assess the electricity price required to make a bioenergy project financially viable. The commercial decision to build a bioenergy plant is made on a similar basis to any large industrial project. When a company or investor is asked to finance a bioenergy project, it is essential that they understand the way the project will be developed and the time it will take to realise the return on investment. Table 5-2 shows assumptions used for the financial analysis.

Table 5-2: Assumptions for the Economic Analysis of Bioenergy Systems

Model Input	Assumption Used
Project life	15 years from first investment
Residual value of plant	Assumed to be nil
Construction period for the plant	12 months for 0.5 MW option 18 months for 5 MW option 24 months for 20 MW option
Commissioning period	Included in construction period
Production ramp up	Immediate full production and full product purchase
Inflation of costs and revenue each year	2.75% for costs 2.75% for revenue
Depreciation	Straight line over 15 years
Company tax rate	28%
Interest on any borrowings	10%, with principal repaid at end of project
Financing	50% equity financing
Plant operation	8,000 hours per year (providing a capacity factor of 91% and allowing time for scheduled shutdowns and maintenance)
Required project IRR	15% after tax
Working capital	Not included

Figure 5-6 shows the relationship between plant scale and the corresponding electricity price needed for a commercially viable project and how this impacts on the capacity to pay for biomass feedstock. For small plants, capital cost is the major cost element, making it important that use of the plant is maximised to improve fixed cost recovery. For large plants, the unit capital cost has dropped and the largest single cost is expected to be feed purchase. Therefore the lowest cost feedstock is most desirable.

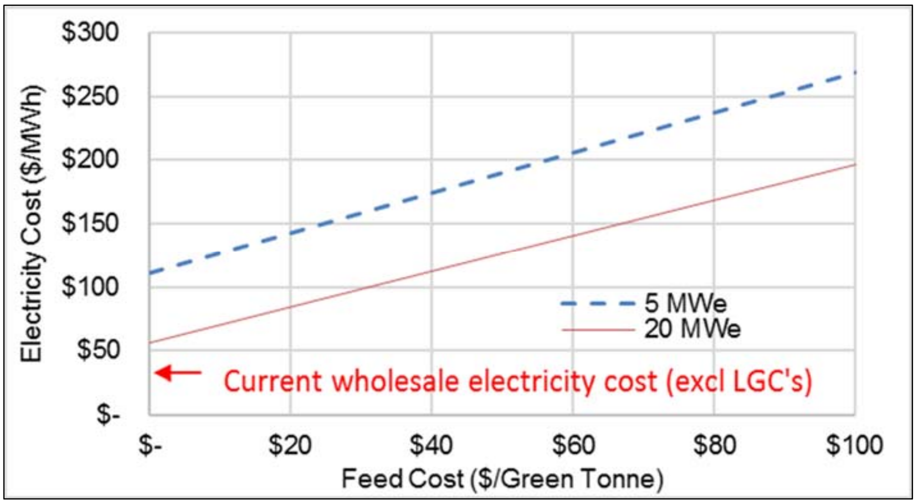
[37] Assumed to be at 50% moisture content

A key trend from this analysis is that the sale price for electricity increases at a linear rate with increasing feed cost. Figure 5-7 shows the relationship between feedstock price and electricity price for the 0.5MW, 5MW and 20MW plants that were modelled. The electricity prices shown do not include any LGC values which are utilised in a separate part of the overall model.

Increased capital, operating and maintenance costs raise the required electricity price. Capital structure also has an influence, with higher electricity prices required as levels of equity increase.

The average price for wholesale electricity in Tasmania for 2014/15 was $37.16 per MWh according to data published by the Australian Energy Market Operator[38]. Over the same period the Clean Energy Regulator estimated that the volume weighted average market price for a LGC was $29.38[39] (applicable for each MWh of eligible renewable electricity). This would suggest a general target for large-scale, commercially-competitive renewable electricity of $37.16 + $29.38 = $66.54 per MWh, which is less than half the cost of electricity generation under three alternative bioenergy scenarios summarised in Figure 5-7.

Figure 5-6: Impact of Plant Scale on Capacity to Pay for Biomass



Source: Enecon

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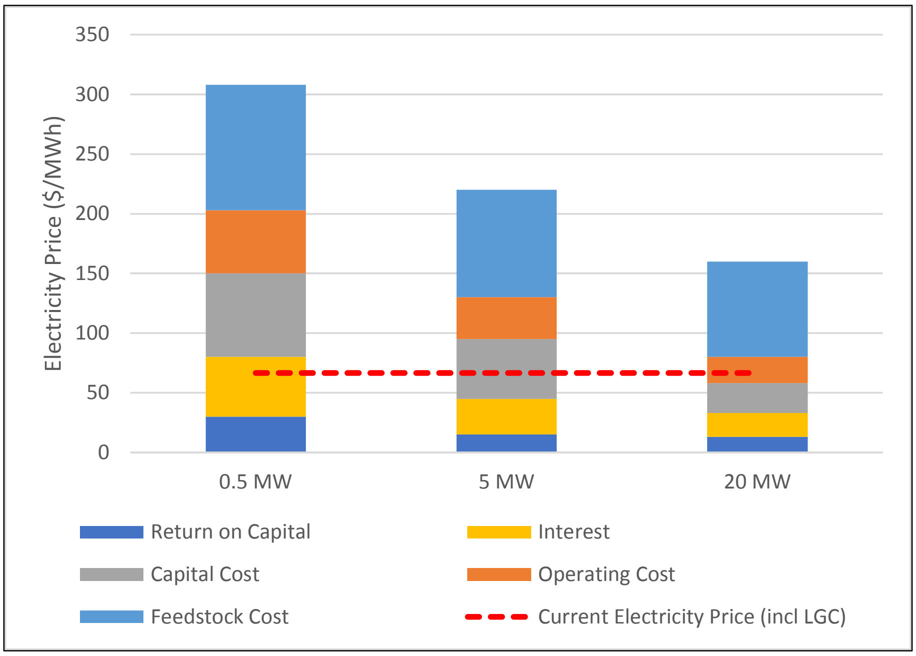
38 http://www.aemo.com.au/Electricity/Data/Price-and-Demand/Average-Price-Tables

39 http://www.cleanenergyregulator.gov.au/RET/Scheme-participants-and-industry/Industry-assistance/Industry-assistance-published-information/Volume-weighted-average-market-price-for-large-scale-generation-certificates

Figure 5-7: Electricity Price as a Function of Plant Capacity



Source: Stucley *et al* 2012

Figure 5-7 shows that based on the assumptions noted previously and the typical price payable to support renewable electricity, development of a stand-alone bioenergy plant would exceed the current cost for wholesale electricity.

Even assuming a zero cost feedstock and the ceiling price for LGC's of $65/MW, a new plant appears unlikely to be viable. It could be argued that increasing the price for LGCs would improve the viability of such plants, however any increase to LGC prices would also improve the viability of wind and solar projects.

Biomass power plants are well suited to provide baseload power, but are not as well matched to supply variable and intermittent demands. Therefore it is not feasible to consider operating these combustion facilities periodically during times of peak power demand.

End Markets and Feedstock Availability

A wide range of technologies and equipment is available to carry out biomass combustion, which makes it possible to use a wide range of feedstock. Combustion systems can utilise softwoods and hardwoods including wood, bark and other residues. It is generally not necessary to dry the feed before use, as combustion systems can be designed to utilise feed with the moisture content of fresh wood. It is also possible to design systems that can utilise a range of particle sizes, from sander dust and sawdust through to large pieces of wood.

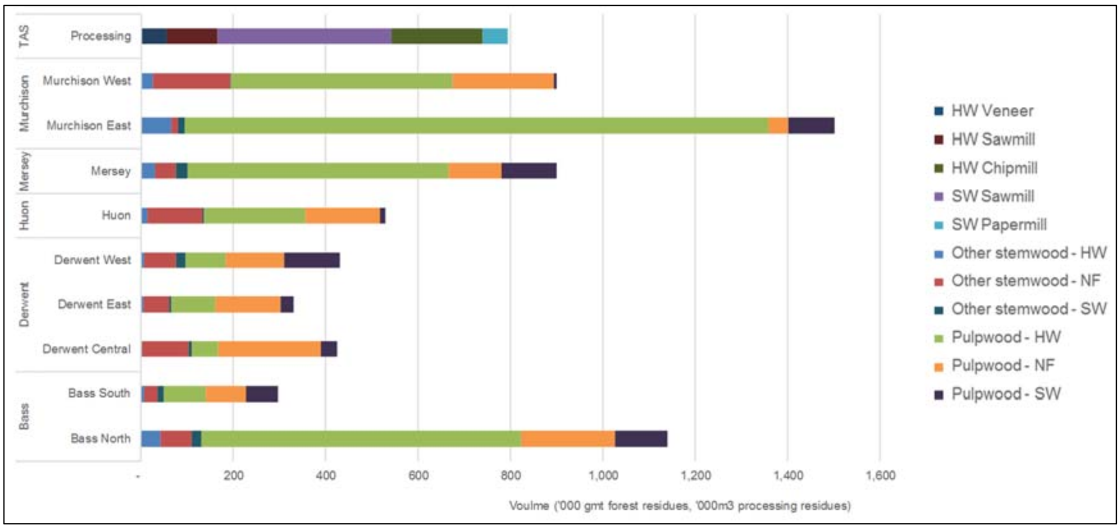
One important requirement is to match the plant design to the feedstock, and once constructed not to subsequently vary the feedstock significantly from the original specification the plant was designed for. It is also important to minimise the contamination of biomass feed, with impurities such as soil or stones.

Figure 5-8 shows the regional distribution of forest residues by type and processing residue by source. Other Stemwood is included in the volume data as it could potentially be used as a feedstock provided it was economic to do so.

All regions have the capacity to deliver up to 280,000 tonnes of residues which is sufficient for a 20MW bioenergy facility. However, as Figure 5-7 shows, bioenergy plants constructed solely for electricity generation to supply the grid have a very low capacity to pay for fibre.

The viability of a bioenergy project is sensitive to the delivered cost of the feedstock and the distance to connect the facility to the grid. The delivery distance to the consumer through the existing grid infrastructure has less impact on commercial viability than these two costs. Any potential bioenergy project would therefore be located as closely as possible to its biomass source. Once the supply sources have been identified, the plant location would be located to minimise the delivered feedstock cost.

Figure 5-8: Regional Distribution of Residue Availability in Tasmania



Source: FT, PFT, NCFFI (unpubl)

Pathway for Residue Utilisation

The data above indicates that a stand-alone bioenergy plant built solely to generate electricity for the grid would not be commercially viable based on the current price for wholesale electricity. At some stage in the future it may be possible to meet an increase in electricity demand via new biomass-fired generators located strategically within the grid. Under these circumstances, a bioenergy development may be a more cost-effective option than an upgrade to the grid itself.

No such opportunities were identified by TasNetworks at this time. Any future opportunity would need to be considered individually to account for the variability of scale, location, feedstock availability and cost, and the relative costs for a grid upgrade compared to construction of a biomass power plant.

The commercial viability of producing electricity from biomass may be improved if the electricity generation is part of a cogeneration plant, which benefits from customers for heat as well as power. This option is considered in the following section of the report.

Table 5-3 summarises some of the key considerations for further development of stand-alone bioenergy.

Table 5-3: Summary of Key Considerations for the Development of Stand Alone Bioenergy in Tasmania

Criteria	Key Considerations
Key Success Factors	Sufficient quantities of biomass available to support a large-scale bioenergy facility Mature technologies available for combustion and power generation
Key Challenges	Cost competitiveness relative to conventional electricity and also to other forms of renewable electricity such as wind Lack of growth in Tasmania's electricity demand
Barriers to Entry	As above
Collaborators	Major engineering contractors and equipment suppliers can provide turnkey plants if commercial circumstances ever favour such developments
Competitors	Electricity from local wind and hydro and via the Basslink undersea cable
Policy Considerations	Federal government policy already provides support for renewable electricity generated through to 2030 when the RET scheme finishes
Potential Timeframes for Further Development	No immediate opportunities identified Any future demand will depend on timing, location and scale of upgrades to the Tasmanian electricity network

6. COGENERATION

6.1 Option Summary

Stand-alone Combined production of Heat and Power (CHP) plants are common in some European countries which is a reflection of policy support and subsidies as well as the status of existing district infrastructure for the distribution of both electricity and heat. In Australia, the existing infrastructure arrangements mean cogeneration opportunities are largely limited to the industrial and commercial sectors.

Demand for cogeneration is very site specific and requires the alignment of demand for electricity and heat with sufficient quantities of feedstock to meet the capacity of the system.

Cogeneration has relatively modest fibre inputs; a 15MW facility, which is large by Australian standards, would require residue feedstock of approximately 54,000 green tonnes/year to run at full capacity. Existing cogeneration facilities typically rely on feedstock generated within close proximity or have access to low cost residues (such as sawdust) with limited alternative commercial markets. This indicates a market preference for processing residues rather than biomass sourced directly from forests.

Key sectors of the Tasmanian economy that utilise large amounts of heat and could be considered prospects for cogeneration include the wood processing sector, the dairy sector, vegetable processors and the minerals processing sector. Potential sites for cogeneration match the heating requirements of particular facilities, proximity and volume of feedstock, and capital requirements for the cogeneration plant.

The commercial success of cogeneration depends on at least five separate variables: the scale and variability of energy needed; existing costs for heat and electricity; cost to secure biomass; equipment requirements; and meeting the required investment return. Each variable has a wide input range and the interaction between them means each cogeneration opportunity must be considered on its own merits.

Provided the heat requirements are compatible and the other key criteria associated with these variables are met, it may be possible that heat and electricity produced at one site could be distributed to a number of industrial users. This allows for further consideration of the benefits associated with economies of scale and maximising utilisation, both of which are key drivers of the capacity to pay for biomass.

6.2 Cogeneration Markets

Cogeneration involves the Combined production of Heat and Power (CHP), usually via a combustion process such as those described in the chapter on electricity generation. The particular benefit of cogeneration is that the recovery of useful (and valuable) heat and energy from the biomass will be greater than if it is used solely for electricity generation. Electricity generation from biomass via a combustion plant typically achieves conversion efficiencies (biomass energy recovered as marketable energy) in the range of 20 to 30%. However, depending on customer needs and plant configuration, cogeneration can achieve double or triple these conversion efficiencies. The recovery of additional energy as heat can create a more compelling commercial argument for the construction and operation of a bioenergy plant.

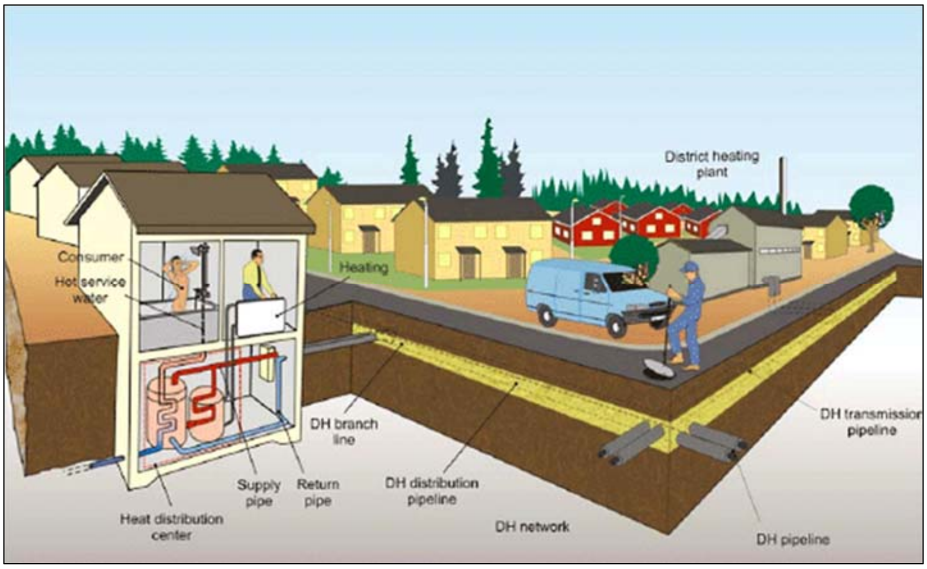
Market Demand for Cogeneration

In Europe the bioenergy industry has expanded rapidly over the last 10-15 years to the point where it is now the largest form of renewable energy production in the region. The development of this sector has been assisted through substantial policy support and subsidies from countries within the European Union (EU).

Stand-alone CHP plants are common, particularly in north western European countries. Some are substantial with the Avedore 2 plant near Copenhagen, Denmark, producing large enough quantities of energy - 570MW of heat and 585MW of electricity – to rival Australia's large coal-fired power stations. The electricity is fed directly into the grid while the heat produced from the plant is used for district heating. Energy conversion efficiency is 49% for electricity generation only, and reaches more than 90% when electricity and heat are both produced, making this one of the most efficient energy plants in the world. It is the utilisation of heat for district heating that underpins the viability of many of these European cogeneration plants.

District heating involves the distribution of heat to domestic and commercial users, typically via hot water circulated in insulated underground pipes that are installed through cites or towns. The associated heating systems within buildings are based around heat exchangers that extract heat from the reticulated hot water and circulate it through a closed system within the building, as indicated in Figure 6-1.

Figure 6-1: Schematic Showing Infrastructure Layout for District Heating



Source: Living Energy NZ

Use of district heating in Europe varies from country to country. Denmark uses district heating for more than 60% of its space heating and hot water needs, whereas in Germany the figure is 14% and usage is primarily in cities such as Munich and Berlin.

Rothe (2013)[40] identifies a number of key differences between the European use of bioenergy for district heating and Australia:

- **Climate** – Australian winters are far milder than those experienced in central and northern Europe, resulting in a lower demand for heat over the winter months;
- **Housing density** – is far higher in the EU with multi-level residential dwellings common in urban and rural areas. In contrast Australia housing is dominated by single residence dwellings; and
- **Heating infrastructure** – communal residential heating is common throughout the EU, whereas it is rarely used in Australia with most buildings having stand-alone heating systems.

These factors all limit residential demand for heat, a key requirement for cogeneration in the EU.

[40] Rothe, A. (2013) Forest biomass for energy: Current and potential use in Tasmania and a comparison with European experience. Available at: http://www.pft.tas.gov.au/images/biomass_report_rothe_170713.pdf

Energy terminology:

W stands for Watt, the metric unit equivalent to the delivery of one Joule of energy per second. Thus a megawatt, or MW, is equivalent to 1MJ of energy delivered per second.

When the energy output of a system is described it is often presented as heat or as electricity:

MWth = 1MW of thermal energy

MWe = 1MW of electrical energy

One MWth is one MW delivered for one hour (3,600 seconds). It is therefore equivalent to 3,600MJ, or 3.6GJ of energy. In this way it is possible to consider the energy in wood as GJ and the energy output in MW, through knowledge of the length of time that the energy output is delivered.

In Australia, cogeneration is largely limited to the industrial and commercial sectors. The wood processing sector is already a substantial user of on-site residues for heat and energy. If domestic firewood is not considered, the main use of woody biomass for bioenergy in Australia is in wood-fired combustion units providing industrial heat. Table 6-1 identifies a number of industrial facilities in Australia utilising woody residues to generate thermal heat.

Table 6-1: Examples of Wood Fuelled Industrial Heating Systems in Australia

Company	Location	Heat Produced (MWth)	Heating Method
Nestle	Gympie, QLD	16.0	Water tube boiler
Hyne & Son	Tumbarumba, NSW	15.0	Thermal oil heater
Carter Holt Harvey	Oberon, NSW	12.0	Thermal oil heater / Fibre drying
Carter Holt Harvey	Gympie, NSW	10.0	Hot gas – dryer
Carter Holt Harvey	Tumut, NSW	20.0	Hot gas – tunnel dryer
Bega Cheese	Bega, NSW	12.0	Not specified
AKD Sawmills	Colac, VIC	15.0	Thermal oil heater
Hyne & Son	Tuan, QLD	12.5	Thermal oil heater
Laminex	Gympie, QLD	24.0	Thermal oil heater
Visy	Tumut, NSW	30.0	Water tube boiler

Source: Stucley *et al.* (2012)

In addition to using woody residues for thermal heat, a number of facilities utilise other types of residue to create heat alone or heat and electricity. Examples in Australia include:

- Large cogeneration facilities in the sugar industry, where waste fibre (bagasse) is used in plants that typically generate process heat for the associated sugar mill and 30 MW or more of power for mill use and export via the electricity grid;
- Australian Tartaric Products in Victoria recently installed a 10MWth boiler fired by waste grape skins (grape marc). This boiler provides process heat for the site and, when it has unused capacity, steam is sent to a 600kWe Organic Rankine Cycle (ORC) unit for on-site power generation; and
- Cogeneration has been achieved by adding small ORC units to existing heat plant in sawmills, generating heat for kilns and electricity for use on site. Examples include a 70kWe demonstration unit at Reid Brothers sawmill in Victoria and a 240kWe unit at Gympie Timber Company in Queensland.

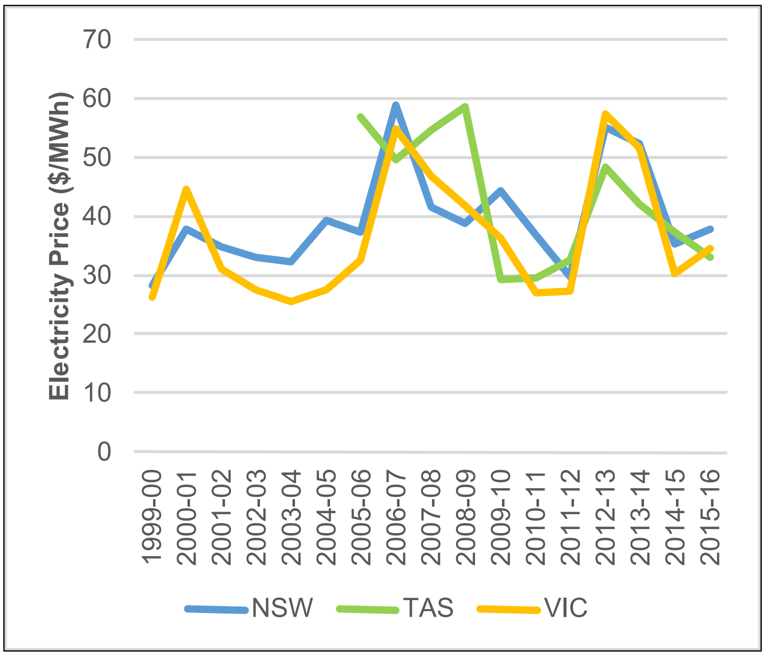
The key to the viability of many of these projects is having access to a low cost feedstock that is either generated on-site, or can be purchased from other manufacturers. For biomass, such feedstocks may be chipped wood or sawdust, shavings etc. The combustion plant must be designed according to the characteristics of the feed to be used taking into account factors such as particle size and moisture content. The nature of the residue feedstock depends on a range of factors including consideration of alternative markets (such as the pulpwood market in the case of woodchips) as well as the cost of energy from alternative fuel sources.

Energy Price Trends

Two of the key drivers for considering cogeneration are the cost of electricity and natural gas (for heat). Figure 6-2 shows the trend price for electricity in Tasmania, Victoria and New South Wales. It illustrates wholesale electricity prices are volatile but typically range between $28-60/MWh. Retail electricity prices can vary from less than $100/MWh to more than $200/MWh.

The wholesale gas market in eastern Australia has much less pricing transparency as the market is dominated by long term bilateral contracts between gas producers and consumers. At the retail level, prices also show significant variation. Confidential data provided by several industrial users of gas and electricity suggest that retail gas prices currently range from less than $10/GJ for very large users to almost $20/GJ for small users.

Figure 6-2: Nominal Trend in Wholesale Electricity Prices



Source: AEMO

Because of this variation, and the potential for further volatility in the wholesale price of natural gas, it is not possible to generalise about the commercial viability of wood-fuelled cogeneration plants. Each potential plant must be examined on its own merits.

Price growth for electricity is expected to remain muted in Tasmania as demand for electricity is only expected to increase by 0.8%/ year[41]. In contrast, with the development of the export LNG sector, domestic gas prices may come under significant upward pressure as suppliers seek to align domestic and international prices. International LNG prices are linked to the cost of crude oil. Any increase in gas price over time improves the potential viability of a cogeneration project.

Outlook for Cogeneration in Australia

The theory behind cogeneration is quite straightforward, however the optimal utilisation of equipment varies considerably with the requirements of the energy consumer(s). Optimal equipment utilisation minimises the capital payback period. The development of commercially

[41] TasNetworks Corporate Plan Planning Period: 2015–16 to 2019–20

viable cogeneration projects may be influenced by a range of factors, including some that will be specific to the energy consumer/site in question. These include:

1. **Variability of use for both electricity and heat** within the consumer's plant each day, week and season. A bioenergy cogeneration plant represents a significant capital cost and its commercial viability is improved if its hours of operation are maximised.
2. **Scale** – larger cogeneration systems offer lower unit costs because they achieve economies of scale. However, building a larger cogeneration plant may also mean that for extended periods it only achieves partial utilisation because of the consumer's variable energy needs. Electricity export is possible but the associated complexities, grid connection costs, and lower financial returns for exported electricity versus on-site use can mean that electricity export may be of limited benefit relative to the additional capital costs incurred.
3. The consumer's **ability to meet current and future energy needs** with existing heat plant. Cogeneration has a better chance of commercial viability if it is introduced to coincide with planned system changes and capital expenditure outlay.
4. **Electricity to heat ratios** vary with overall configuration and equipment selection. So the relative costs for heat and power within the consumer's plant and the ability to supply base load for one or the other will influence the choice (and size) of equipment.
5. **Available space** within, adjacent to, or at some distance from existing energy plant. In addition to the cogeneration plant itself, space is required for construction and then for delivery and storage of biomass feed, ash handling as well as routine and major maintenance.

A significant proportion of industrial heat plants in Australia use natural gas as their energy source. Gas is widely used in Tasmania, including within the wood processing sector where some sites use it in preference to wood residues for process heating. When comparing industrial heating systems fuelled by natural gas or biomass there are some fundamental differences in their costing and operation. Natural gas systems typically have:

- Lower capital cost than bioenergy systems of equivalent scale;
- Higher fuel costs than bioenergy systems of equivalent scale;
- Are generally able to respond to load variations more quickly than bioenergy systems; and
- Offer reliable fuel supply (gas) via well established, low risk infrastructure.

Because of these differences, natural gas systems may be better suited, technically and commercially, to intermittent, seasonal and variable heat loads. Such variable loads are widespread in industry and this can place technical and commercial barriers in the way of bioenergy.

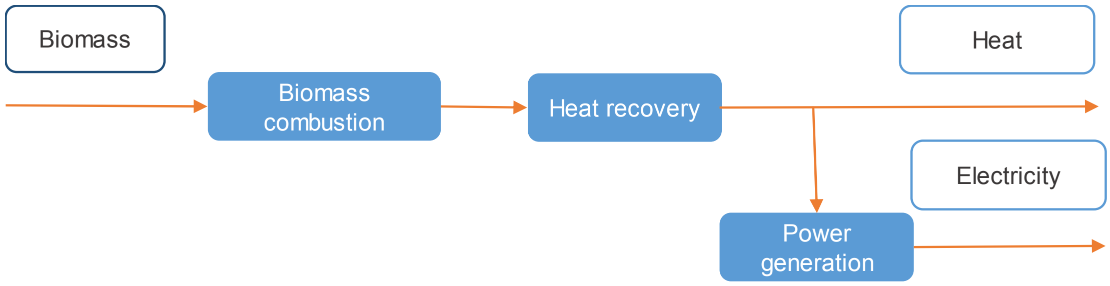
Bioenergy systems ideally require consistent and continuous energy demand (i.e. 24 hours per day and seven days per week for the whole year). In addition to being technically preferable it also maximises the opportunity to recover capital costs. Energy loads that are variable, intermittent and seasonal can create difficulty in the operation of a bioenergy plant through increased stress on equipment and reduces the ability to recover capital costs in a timely manner.

6.3 Technology and Proponents for Cogeneration

To justify a cogeneration project there must be a reliable, long term need for both heat and power. In some cases, the primary need will be process heat, and in others it will be power. This leads to two alternative pathways to describe the basic configuration of a cogeneration project.

Plants to generate heat for cogeneration use similar equipment as that used for electricity generation. When high grade heat (such as thermal oil or steam) is the primary need, a cogeneration plant will generally have the following configuration.

Examples of this configuration include the ORC cogeneration units added to sawmill heat plants as described previously.

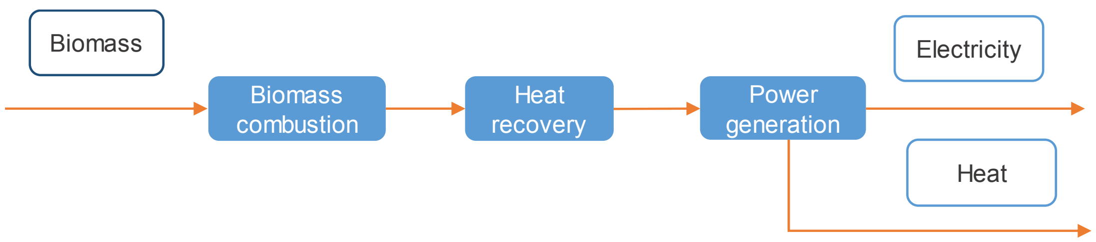


Heat recovery equipment will be designed to provide heat in the form that best suits the local need; this is generally as steam but can also be as thermal oil. For such plants, power generation can occur in two different ways:

- The combustion and heat recovery sections can be sized for CHP needs, allowing each need to be met independently of the other; or
- If the process heat requirement is variable, power generation may be designed to occur only when there would otherwise be unused capacity in the combustion and heat plants. The overall capital cost will be lower, but the availability of electricity from this plant will be dictated by the need for process heat. One benefit of this approach is that it allows the combustion and heat plants to run within optimal operating ranges, which may otherwise be hard to achieve if the process heat load varies significantly.

The efficiency of these plants varies with configuration. For example, the gross electrical efficiency of ORC units can vary from as low as 8% to more than 25%, depending on the equipment scale, the temperature of heat supplied to the ORC and whether low-grade heat is used elsewhere on the site. The net efficiency (i.e. the electricity that may be used elsewhere on the site or exported to the grid) will be impacted by equipment selection and the use of electricity to operate the cogeneration plant.

If process heat is not the primary need of the system, or if the consumer requires low grade heat, an alternative configuration may be used.



Examples of this type of plant include power generation via:

- A pass-out steam turbine, which has the ability to generate electricity while simultaneously releasing some of the steam at a suitable pressure for a process heating role; or
- An ORC plant that may be set up to generate electricity and release its exhaust energy as hot water (at up to 120^{0}C), typically for washing or low temperature process heating.

The technology for either process is readily available but each option is a bespoke opportunity with technology adapted to the requirements of individual sites.

It is possible to use turnkey contractors to build large cogeneration plants such as those installed at sugar mills. In these cases a single company takes responsibility for the design, supply, installation and commissioning of the unit. The company is typically a large international equipment supplier or a large engineering contractor.

The turnkey approach can also be used for smaller plants, but it is more common to use a range of component suppliers, consultants and contractors, with the energy user or the project developer assuming control for the overall development of the project. The cogeneration plant at Australian Tartaric Products was built using this latter path.

6.4 Social and Environmental Considerations

The environmental and social impacts associated with the combustion element of cogeneration are the same as identified in the electricity generation chapter.

The economics of cogeneration mean there is a preference for processing residues. While forest residues could potentially provide some of the feedstock, developments to date suggest this is an unlikely outcome. This means most energy would be sourced from residues created from within the mill gate or nearby facilities where it is economic to transport between sites. The more feedstock that is sourced from within the gate, the less movement of fibre is required. If these residues are currently being diverted to landfill, then there is a double net benefit as steam is created from a renewable resource (displacing fossil fuel based natural gas) while landfill volumes would decrease.

A cogeneration facility has a higher level of complexity than a stand-alone biomass electricity generation facility. This is particularly the case if the heat was distributed outside of the mill gate to other industrial facilities. This could increase the environmental impacts due to:

- An increase in capacity to achieve economies of scale; and
- Construction of the infrastructure necessary to connect the mill to other heat users.

From an employment perspective, a larger cogeneration facility would have a higher labour requirement from a plant operation and technical support perspective.

6.5 Prospects for Cogeneration Development in Tasmania

Opportunities for cogeneration in Tasmania exist at any industrial site where there is a significant requirement for heat. The electricity that is coproduced with that heat could be used at the same site, at an adjacent site via a localised grid, or at a remote site via the state grid.

The introduction of natural gas to Tasmania in 2002 has resulted in a significant take up by a number of industrial and residential users for heat supply. Total use of natural gas in Tasmania from August 2014 to July 2015 was 6.7 million GJ[42]. Gas use by the Tamar Valley Power Station was negligible during the period, and with industrial and residential consumption split at approximately 60/40[43], the consumption of gas for industrial use was approximately 4 million GJ.

Coal is also used for industrial heat, primarily by Cement Australia (who own the coal mine) at the Railton cement works, and at the Norske Skog pulp mill at Boyer. While the value of the coal is not known, Norske Skog have made a commercial decision to use more than 90,000 tonnes of coal per year[44] rather than local biomass residues.

The use of liquid fuels for heating in Tasmania is limited to use of LPG where natural gas is not available. We are not aware of any significant industrial users of LPG in the state.

[42] http://www.tasmaniangaspipeline.com.au/pipeline-stats

[43] Adapted from Section 1.4 of Energy Strategy Issues Paper – Department of State Growth, 2014. Residential demand may include some commercial users

[44] Norske Skog Tasmanian Energy Strategy Submission, September 2014

End Markets and Feedstock Availability

Key sectors of the Tasmanian economy that utilise heat and could be considered prospects for cogeneration include:

- Wood processing sector – heat used for drying timber and other wood products;
- Dairy sector – heat used for spray driers in the production of milk powder;
- Vegetable processors; and
- Minerals processing – heat used for various process activities.

As noted previously, domestic heating is unlikely to represent a viable large-scale market for thermal heat as the nature of house construction in Tasmania is not conducive to the development of a centralised heat distribution system. Heating multi-storey buildings such as hospitals using biomass does represent a market opportunity. However, these types of energy systems require relatively small volumes of biomass to operate, typically only a few hundred tonnes of biomass feedstock per year.

For example, Beaufort Hospital in Victoria installed a 110kW biomass boiler to augment its existing LPG heating system. The boiler requires an input of approximately 200 tonnes of woodchips/ year. Importantly this initiative was not undertaken on a purely commercial basis and received state government funding. The rationale for funding was to raise awareness of biomass as an energy source.

Green wood chips at 40% moisture content have an energy value of approximately 10 GJ/green tonne. With slightly higher conversion efficiencies for gas-fired heat plant over biomass-fired heat plant, and assuming that all natural gas used by industry is for heating, the entire industrial market for natural gas heating in Tasmania is equivalent to approximately 400,000 green tonnes/ year of wood residues.

Figure 5-8 in the previous chapter highlights there are substantial processing residues available with concentrations of fibre availability (of both processing and forest residues) around the townships of Burnie, Smithton, Georgetown, Scottsdale and Huonville. Industrial facilities located around these townships would represent the most prospective opportunities for cogeneration.

Economic Considerations

To demonstrate the economics of cogeneration a case study was developed to present an example of heat and power generation via bioenergy, and comparative costs for heat from natural gas. It seeks to highlight the relative costs for these two fuels, and the impact of full and partial utilisation of energy equipment.

This case study is based on a hypothetical site that uses steam to provide up to 15MW of process heat. Electricity is also used on the site. A 15MWth boiler is considered for heat production, and several alternative uses for the heat are modelled to determine the performance of bioenergy, on its own and as an alternative to natural gas.

The scenarios considered are:

1. Supply of process heat only with three varying levels of demand:
    a. A heat load that requires the boiler to operate at 100% capacity on a continuous basis. In this scenario there is no spare boiler capacity to allow for electricity generation.
    b. Supply of process heat only, but with the process heat requirements varying such that, on average, only 50% of the boiler capacity is needed to provide process heat.
    c. As for scenario 1b but with process heat demand using only 25% of boiler capacity.

2. Cogeneration - assuming the boiler is providing all necessary process heat with 50% of its capacity with electricity generated using the remaining boiler capacity, for either:
    a) Sale to the grid (at wholesale electricity prices), or
    b) Localised use (to reduce the purchase of electricity from the grid at retail prices).

Modelling Assumptions

Boiler and ORC turbine/generator prices were sought from experienced equipment vendors. Industry factors were applied to allow for other costs such as civil works, installation and commissioning. Maintenance and operating costs were based on industry practice. This data was combined to develop a financial model based on the following assumptions:

- Plant construction, then 100% availability from year 2 onward;
- 2% inflation;
- 50% debt financing with a 6% interest rate;
- 15 year project life;
- Straight line depreciation;
- 30% tax rate;
- Target internal rate of return 15% after tax;
- Plant operation is assumed possible for a maximum of 8,000 hours/ year, leaving approximately 10% of the year for scheduled maintenance and occasional unscheduled stoppages; and
- Biomass is assumed to be green wood chip with a small amount (< 5%) of bark and a calorific value of 10GJ/tonne.

While based on actual equipment pricing, these data should only be considered indicative not as costs for a specific site. Costs for an actual project will be influenced by a number of site-specific factors, including:

- Location and site conditions;
- Actual variation in load and ability for equipment to function effectively within such variations;
- Biomass feedstock(s) (e.g. moisture content, particle size, bark or leaf content); and
- Equipment scale (attended or unattended operation) and selection (e.g. low cost and low efficiency or high cost and high efficiency).

Installed costs

The estimated equipment purchase and installation costs, including civil works and any other ancillary needs were:

- Biomass boiler 15MWth $9.5 million
- Natural gas boiler 15MWth $3.6 million
- ORC unit for 3.5MWe gross output $5.9 million

Scenario 1) Heat utilisation only

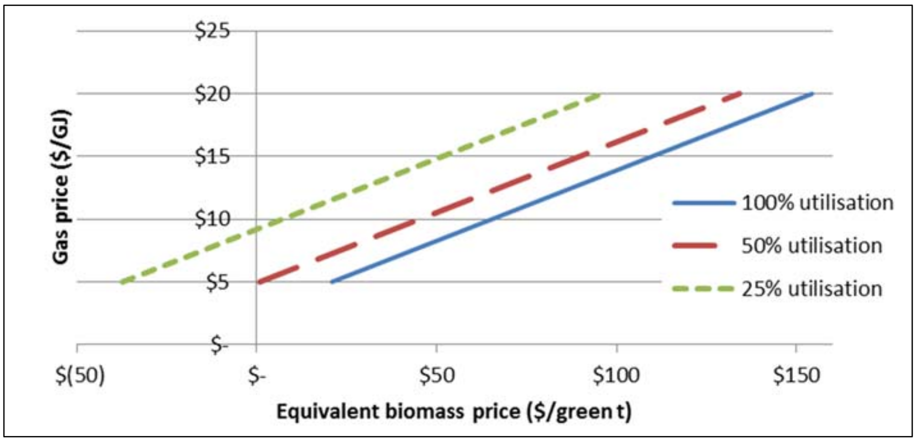
Figure 6-3 shows the relationship between the capacity to pay for biomass to provide 15MWth of steam and the price for natural gas. Three alternatives are shown:

- Operation at 100% of plant capacity on a continuous basis (24 hours per day and 7 days per week, with routine allowances for maintenance). For such operation, the requirement for green wood chip would be 54,000 tonnes/year, based on a typical boiler efficiency of 80%;
- Operation at 50% of full capacity, which could be the case for a site with reduced hours of operation and/or some operation at partial load; and
- As above but at 25% of full capacity.

For a range of gas prices Figure 6-3 shows the equivalent price that could be paid for green biomass to provide bioenergy. Retail natural gas prices to industry vary from less than $10/GJ to more than $20/GJ. For a mid-point of $15/GJ, a biomass boiler operating at 100% of capacity using biomass at $110/green tonne would offer equivalent profitability.

If the boiler is only operated at 50% capacity for process heat, the fixed costs must be recovered from a reduced energy output. The biomass boiler has a higher fixed cost than the natural gas boiler, so the competitive position for biomass relative to natural gas is reduced. In this example if the cost of natural gas is $15/GJ, the equivalent biomass cost should not exceed $90/green tonne. If gas is $15/GJ and boiler operation is at 25% the equivalent biomass cost should not exceed $52/green tonne.

Figure 6-3: Capacity to Pay for Biomass with a 15MWth Biomass Boiler Using 100%, 50% and 25% Steam Utilisation



Source: Enecon

This case study assumes 50% or 25% operation of the biomass boiler, without any consideration of how its turn down ratio (the ability of the boiler to operate at partial load) may influence its use on a site with variable heat requirements. The boiler should be designed with the expected load variability in mind.

For example, on a site that operates for two shifts per day then has no need for heat or power on the night shift or at weekends, the boiler may be placed in “slumber” mode for night shift, quickly restarted at the beginning of the new day shift and switched off at the weekend. Any reduction in operation reduces the efficiency of the boiler and therefore capacity to pay for biomass. In this example reducing the boiler output overnight and shutting it down for weekends would reduce the level of utilisation to slightly below 50% capacity.

Economies of scale

This example has been developed for a large industrial boiler that offers economies of scale over smaller units. At $9.5 million installed and 15MW capacity it represents a cost of $633,000 per MW of installed capacity.

By comparison, the 110kW biomass system at Beaufort Hospital had an installed cost of $440,000[45]. This is equivalent to $4 million per MW installed, or six times the unit capital cost of the 15MW plant. The variation between these two examples shows that the scale of the proposed cogeneration system (which reflects the local heat requirements) is a critical factor in determining the commercial viability of the project.

Such economies of scale mean that large heating and cogeneration systems are more commercially attractive than small systems, provided there are suitable uses for the heat and power produced. This may be achieved by a single, large industrial customer. It may also be feasible if several energy users in close proximity share the outputs of a heat plant or cogeneration plant. If one of the local businesses is a wood processor with wood residues, those residues may be suitable for use in a bioenergy plant that then provides heat and power for the wood processor and also for its neighbouring industries. The feasibility of local reticulation for heat and power will be site specific. Electricity reticulation is via underground cables or overhead power lines and can conceivably take place over greater distance with less cost and energy loss than would be the case for heat reticulation, which involves insulated pipework.

Scenario 2) Cogeneration

This scenario examines the situation where a biomass boiler is already installed but is only partially utilised for process heat. Its unused capacity can therefore be exploited for electricity generation. If the boiler is already installed, the additional costs to produce electricity will be for the supply, installation and operation of the electricity generation plant (in this case study an ORC turbine/generator) and purchase of additional biomass feedstock for the boiler (to shift from partial use to full use of boiler capacity). The revenue stream to justify such expense comes from sales (or avoided purchases) of electricity and LGCs.

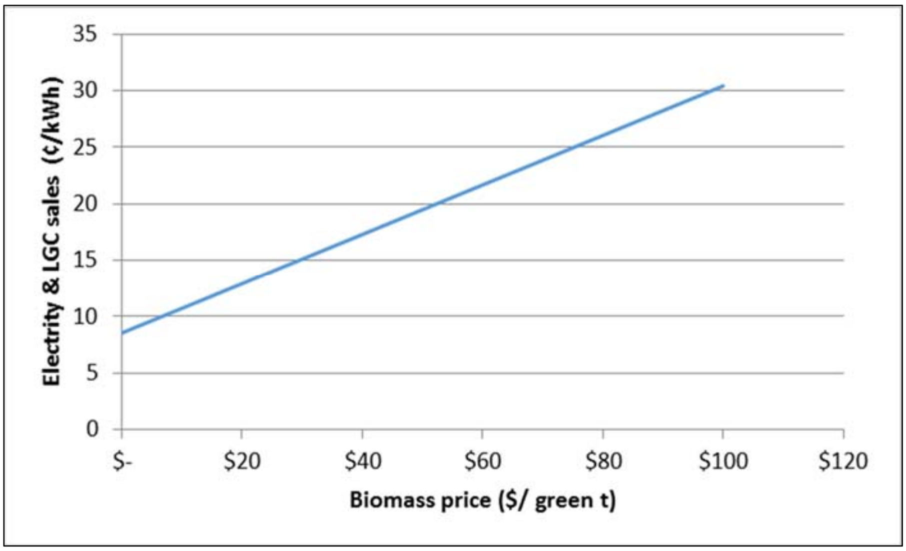
Capital payback provides a simple method of assessing project viability with a five-year payback period often used as an early indicator of project viability. Figure 6-4 shows the relationship between the price for electricity and the equivalent capacity to pay for biomass feed. LGCs are included the electricity price calculations. This example assumes that 50% of boiler capacity is available for operation of the ORC unit. Payback is calculated only for the electricity generation equipment and not the boiler as the latter is assumed to have been justified separately via its supply of process heat.

The electricity generated may be sold into the wholesale market via the grid. Typical revenues from such sales are less than 4 cents/kWh. As with the electricity generation example in the previous chapter, this analysis indicates bioenergy for the supply of electricity generated from surplus steam fed directly into the grid has a very limited capacity to pay for biomass.

Alternatively, when electricity is generated and used on-site it reduces the requirement to purchase electricity at retail prices. Retail electricity prices vary significantly ranging from less than 10 c/kWh to more than 20 c/kWh for industrial users depending on their specific requirements. These avoided purchases effectively form a revenue stream for the generation project and if the avoided electricity was previously purchased at a high price, the viability of the generation project is improved.

[45] Pyrenees Shire Council – Business Case for the Beaufort Hospital Biomass Heating System

Figure 6-4: Electricity Sale Price to Achieve a Five Year Payback on ORC Investment



Source: Enecon

As an example, if the consumer is able to pay 15 c/kWh for electricity from the ORC unit the project can afford to pay approximately $30 per green tonne for the additional biomass required and achieve a five-year simple payback on investment. This calculation is independent of the use of the boiler for heat or the purchase of biomass for that use. It simply takes advantage of unused boiler capacity when the heat load only occurs for part of the time.

This shows there is more upside potential associated with internal use of electricity, and/or sale to a neighbouring user at, or close to, retail pricing, rather than supplying electricity at wholesale price to the external market via the grid.

Scenario Summary

The utilisation of heat at an industrial site, particularly the duration and temporal variability, has a significant impact on the capacity to pay for biomass as an alternative to natural gas. A site with a steady heat load that occurs for much of the year has a better capacity to pay than a site that only operates for a single or double shift on week days and has variable heat requirements during that time. The demand for heat can come from a single source or may involve multiple users.

The two scenarios presented represent a substantial project for supply heat only or heat and electricity in an Australian context. Smaller projects may be feasible, but would gain fewer benefits associated with economies of scale. The analysis demonstrates that in order to maximise the capacity to pay for biomass:

- Heat utilisation must be as high as possible; and/or
- Local electricity utilisation (as opposed to export to the grid) must be capable of exploiting any energy plant capacity that is not being used for heat supply. Such utilisation may be assisted by electricity sales to several industries in close proximity to the cogeneration plant, subject to ease of reticulation to those customers.

Given the variable pricing and use of both gas and retail electricity, any parties interested in pursuing cogeneration will require a specific study of their individual circumstances to determine the project's capacity to pay for biomass.

Pathway for Residue Utilisation

Tasmania has a range of industrial processes that utilise heat in addition to electricity. Potential opportunities for cogeneration may exist within the timber, dairy and meat processing sectors as well as other major industrial gas users.

If biomass were to capture 100% of the Tasmanian market for industrial heat currently served by natural gas, the maximum demand for wood would be around 400,000 green tonnes/year. Achieving a market share of 20% would mean a state wide market for cogeneration of 80,000 green tonnes/year. This volume could potentially be sourced from a number of regions, but would most likely be limited to the wood processing sector. Forest biomass could potentially be used as a feedstock, but is unlikely from an economic perspective.

The market for cogeneration in Tasmania could potentially extend across multiple sectors. Key benefits for the wood processor as the supplier of heat through the combustion of wood residues include:

- The utilisation of residues that may have little or no market value;
- The supply of heat and potentially electricity for internal use at a lower cost than the prevailing retail market; and
- The viability of a cogeneration project may be enhanced if heat demand could be aggregated with other users. While this would be more challenging from a technical perspective it would allow the wood processor to consider the benefits associated with economies of scale and potentially allow for a greater level of heat utilisation, which both have a substantial impact on the capacity to pay for biomass.

A preference for processing residues as a feedstock would suggest locations such as Burnie, Smithton, Georgetown, Scottsdale and Huonville would be the most prospective for the development of cogeneration. These sites have the combination of fibre availability from a range of timber processors as well as industries that require process heat and a substantial demand for electricity.

Within these areas the most favourable sites for locating a cogeneration facility will be where CHP supply (timber processor(s)) and CHP demand (industrial heat users – including timber processors) are located in close proximity to each other.

While there is no minimum or maximum limit for the distance between facilities, the closer the better. As the degree of separation increases the more substantial the interconnecting infrastructure requirement. This increases construction and operating costs as well as the technical difficulty (ease of access for laying cables or pipes). This in turn decreases the efficiency of the operation and therefore project viability.

The technology for cogeneration is well developed with capital and operating costs reasonably well known. Existing transport and electricity infrastructure would most likely be adequate for any cogeneration development. Therefore, it is unlikely any large-scale greenfields infrastructure would be required to develop a cogeneration facility.

Table 6-2 summarises some of the key considerations for further development of cogeneration in Tasmania.

Table 6-2: Summary of Key Considerations for Cogeneration Development in Tasmania

Criteria	Key Considerations
Key Success Factors	Access to low cost feedstock Complementary sources of CHP supply and demand in close proximity to each other Technology and equipment are readily available Commercial viability for each potential plant is based on combination of scale, energy usage, energy price, feedstock pricing, equipment selection and acceptable payback period
Key Challenges	Achieving a scale and utilisation that provide financial justification Uncertainty over gas prices and biomass availability can hinder major capital investment decisions
Barriers to Entry	Capital cost for biomass CHP plants, perceived lack of local precedents and biomass supply chains Understanding individual opportunities
Collaborators	Users of natural gas to generate process heat Wood processors with limited residue markets Specialist consultants for feasibility then equipment suppliers, engineering consultants and installation contractors
Competitors	Natural gas and grid electricity producers, both of which offer flexible, reliable energy with less capital cost than bioenergy
Policy Considerations	National scheme for LGCs for renewable electricity can assist commercial viability, but no equivalent scheme exists for renewable heat State government has the capacity to facilitate potential pan-sectoral opportunities for cogeneration within Tasmania
Potential Timeframes for Further Development	Uncertainty over future gas prices expected to prompt large, stable users to consider alternatives over next few years

7. HYDROCARBON BIOFUELS

7.1 Option Summary

Liquid transport fuels represent the greatest source of energy demand in Australia with diesel (42%) and petrol (33%) accounting for the bulk of the 55 billion litres consumed in 2013/14. Tasmanian demand for petroleum products accounts for around 1.5% of national demand or 850 million litres/ year. As Tasmania has no refining capacity all fuels are delivered in their final form.

Fuel prices are volatile and largely depend on international price developments. Australian retail petrol prices are lower than in most other OECD nations due to lower levels of taxation on fuel. Retail prices in Tasmania tend to be higher due to the same factors which influence regional locations compared to metropolitan centres. These include: lower levels of local competition; lower volumes of fuel sales; lower convenience store sales as well as distance and location factors.

“Drop in” hydrocarbon biofuels can blend in or replace fossil fuels, representing no discernible change for consumers. The development of hydrocarbon biofuels is being driven by policies aimed at reducing greenhouse gas emissions as well as decreasing reliance on fossil fuel imports. Sixty-four countries globally have government policies in place with targets or mandates for renewable transport fuels.

The technologies being developed to produce hydrocarbon biofuels are generally some years away from full commercial deployment. Many of these technologies are at near commercial status in the US and Europe as a result of several billion dollars of government and private investment. Hydrocarbon biofuels can be made from both hardwoods and softwoods via a number of processes, none of which require the addition of hazardous chemicals.

Their potential market in Tasmania is some twenty times that of ethanol blended biofuel, and as such they could utilise most or all of the state’s forest residues. This has the potential to provide the Tasmanian economy with a renewable liquid fuel option based on state generated forest residues. Meeting fuel standards does not appear to represent a material barrier to market, but the status of Australia’s current refining capacity is a considerable risk factor, that could be addressed by building a smaller scale bio-refinery in Tasmania to establish the industry.

The current cost to produce drop in hydrocarbon biofuels exceeds comparable fossil fuel prices. These production costs are expected to decrease over time as efficiencies are realised through technological development as has occurred in the wind and solar energy sectors.

A key benefit of a drop in hydrocarbon facility in Tasmania is it would have the capacity to utilise the existing fuel distribution infrastructure, unlike blended biofuels which would require the development of its own infrastructure.

The likely pathway to development is utilisation of a licensed technology, coupled with a major capital investment in state based refinery capacity. Aligning with existing fuel distributors would be an important factor in the latter stage of the development pathway.

Widespread utilisation of biofuels would have a material impact on greenhouse gas emissions across the transport fuel supply chain. Life-cycle emissions from renewable fuels have been estimated to be some 74% lower compared to conventional petrol.

7.2 Hydrocarbon Fuel Markets

Hydrocarbon transport fuels are mostly derived from the refining of crude oil or natural gas. The refining process produces a range of hydrocarbon products including:

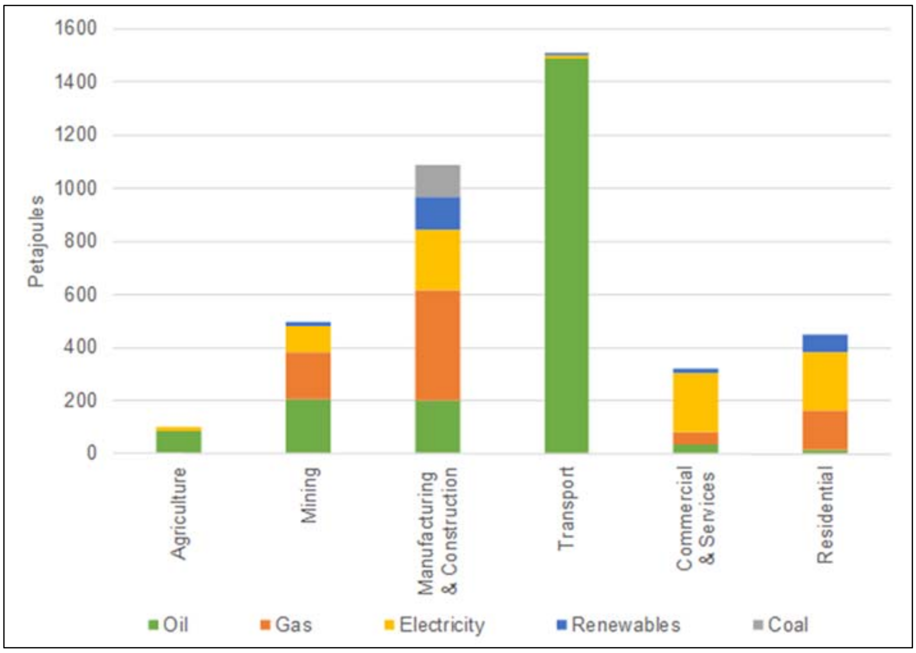
- **Liquefied Petroleum Gas (LPG)** – a gas made transportable by placing it under pressure until it forms a liquid. LPG is used widely by the industrial, agricultural, transport and manufacturing sectors as well as in residential homes for heating and cooking;
- **Automotive petrol** – utilised predominantly by private vehicles (also called "gasoline");
- **Diesel fuel** – primarily utilised by the heavy transport sector;
- **Aviation fuel** – powers turbines used by the aviation sector; and
- **Other products** – used for a range of end uses including bitumen, heavy fuel oil, lubricants, kerosene etc.

Australia produces crude oil and has some oil refining capability, but imports much of its liquid transport fuel needs which are almost exclusively oil-based. As a result, imported liquid fuels have a well-established, stable supply chain from the producer to end markets.

Market Demand for Transport Fuels

Different sectors of the Australian economy utilise energy from a variety of sources. Figure 7-1 shows that oil-based fuels represent Australia's greatest area of energy demand. Oil-based energy is also extensively used by the agriculture, mining and manufacturing sectors.

Figure 7-1: Profile of Current Energy Usage in Australia



Source: Energy Green Paper (2014)

Table 7-1 shows the sales volumes for the main transport fuels in Australia and Tasmania. Current annual Australian demand is around 55 billion litres. Diesel accounts for 42% of national sales with petrol accounting for a further 33%. In recent years the use of diesel has been increasing relative to petrol.

Tasmanian demand for petroleum products accounts for around 1.5% of the national total. Consistent with the broader national trend, petrol and diesel dominate Tasmanian demand accounting for 43% and 44% respectively. The demand for aviation fuel in Tasmania is negligible relative to the use of petrol and diesel.

Table 7-1: Australian and Tasmanian Fuel Sales 2013-2014

Fuel Type	Total Sales Australia		Total Sales Tasmania		
	(Ml/year)	Proportion	(Ml/year)	Proportion	% Australian Sales
LPG	3 845	7%	68	8%	1.8%
Petrol	18 120	33%	363	43%	2.0%
Diesel	23 081	42%	373	44%	1.6%
Aviation fuel	8 168	15%	21	2%	0.3%
Other	1 960	4%	29	3%	1.5%
Total	55 173		854		1.5%

Source: Australian Petroleum Statistics May 2015

Australia's total fuel consumption has been trending upwards over the last four years. The increase in consumption has been driven by diesel and aviation fuel demand, which has risen by 15% and 16% respectively in the period between 2010/11 to 2013/14. Conversely, demand for LPG and petrol has declined over the same period. Sales of LPG decreased by 10% and petrol sales decreased by 3%.

Tasmania currently imports all of its transport fuels, which arrive at one of three receival and storage terminals located at the Hobart, Devonport and Burnie ports. These terminals are operated by refiner-marketers Caltex, Shell and BP[46]. Tasmania has no refining capacity so all fuels are delivered in their final form. Transport fuels are distributed by road from the storage terminal to retailers across the state.

Fuel Price Trends

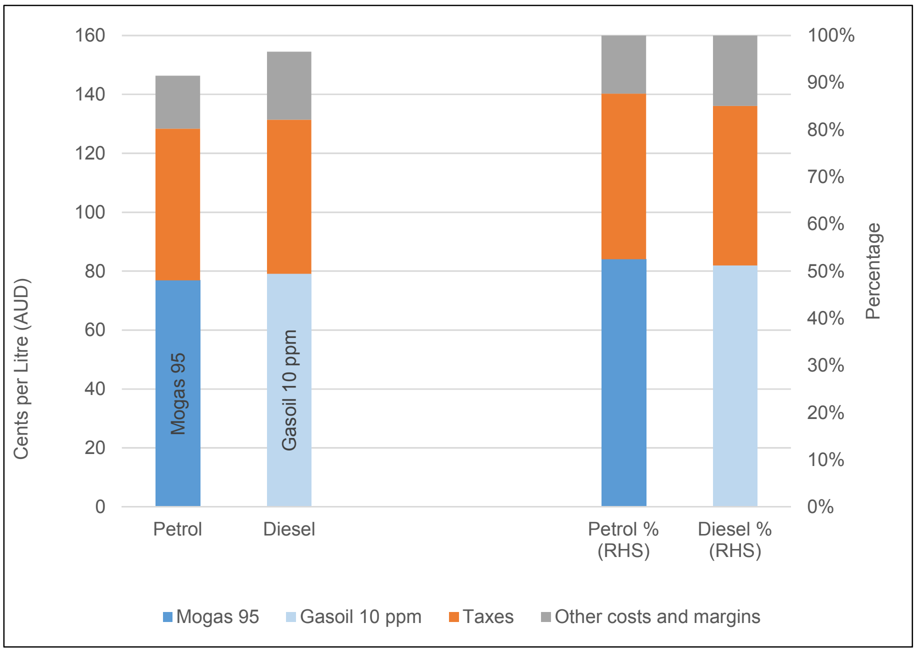
The retail price of transport fuels in Australia is based on four primary components:

- The international price for refined fuel which is traded in United States Dollars (USD);
- The AUD:USD exchange rate. As all imported fuel is purchased in USD the exchange rate affects the purchasing cost in AUD terms;
- Taxes including GST and fuel excise tax; and
- Other distribution costs such as: shipping refined petrol around Australia, terminal and storage costs, fuel delivery, overheads and wholesale/ retail margins.

Figure 7-2 shows the extent each of these components contribute to the overall cost of fuel. Exchange rate movements are not included, but would be reflected in the international fuel price.

[46] Based on "Petroleum import infrastructure in Australia". Prepared by Acil Tasman for DRET, August 2009

Figure 7-2: Composition of Costs for Australian Transport Fuels



Source: ACCC

The average Australian petrol and diesel retail prices in 2014 were AUD1.46/ litre and AUD1.54/ litre respectively. The international oil price component (Mogas 95) accounts for approximately 53% of the retail price for petrol and 51% of the price for diesel (Gasoil 10 ppm). Taxes accounted for 35% of the petrol price and 34% of the diesel price. The ‘other costs and margins’ component varies the most between the two fuel types, accounting for 12% of the retail petrol price and 15% of the retail diesel price.

Australian retail petrol prices are comparatively lower than in international markets. In the September quarter of 2014 Australia had the fourth lowest retail petrol price in the OECD. Australia’s low petrol price is due to the relatively low taxation of fuels, which is 35% compared to an OECD average of 50%.

Figure 7-2 shows that the cost of crude oil accounts for around half of the Australian fuel price. Crude oil prices are determined by international demand and supply dynamics. Supply is largely influenced by OPEC, a cartel of major oil producers. More recently, the expansion of the US shale oil industry has led to a state of oversupply, which in turn has negatively impacted on oil prices at a time when economic growth has slowed in key markets such as Europe, the US and China.

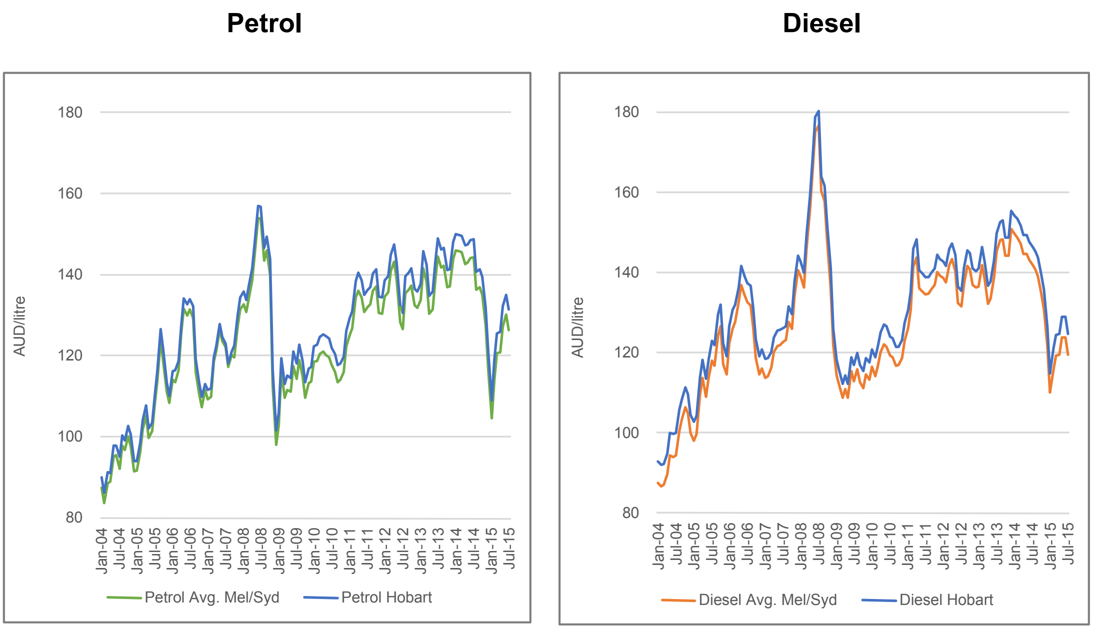
Figure 7-3 shows that crude oil prices are volatile and are affected by periodic price shocks which occur when the supply-demand balance becomes disrupted. Australia's local oil refineries constantly compete with imported petroleum products from large, highly efficient refineries in Asia, regardless of the cost of importing and refining crude oil. Consequently, the price of petrol from Australian refineries is based on international petrol prices.

Figure 7-3: Long-Term Trends in Crude Oil Prices (West Texas Intermediate)

Source: ACCC

The terminal gate or wholesale fuel price is a price for the bulk supply of petroleum products from a fuel terminal where the transfer of ownership occurs once the petroleum products are loaded into a customer's truck at the fuel terminal. The recent trend in terminal gate prices for the main capital cities compared to Hobart is shown in Figure 7-4. It shows wholesale petrol and diesel prices (inclusive of tax) have typically traded between AUD1.00/litre and AUD1.50/litre over the past 10 years.

Figure 7-4: Long-Term Trends in Australian Terminal Gate Prices for Petrol and Diesel



Source: Australian Institute of Petroleum

The cost for both petrol and diesel fuels in Tasmania are typically some five cents per litre higher than equivalent prices for other east coast states. The price differential is affected by the same factors which influence regional locations compared to metropolitan centres. These include: lower levels of local competition; lower volumes of fuel sales; lower convenience store sales as well as distance and location factors. The cost of fuel in Hobart is similar to the cost of fuel in regional Tasmania.

Status of Biofuel Pathways and Markets in Australia

While the vast majority of liquid transport fuels globally are fossil oil-based, there is increasing interest in producing biofuels from renewable organic sources. Biofuels can be manufactured from a variety of feedstocks including sugars, starches, animal fats, vegetable oils, and woody plant material. The transport fuels produced from these sources can also vary, and include hydrocarbons, alcohols, esters and other chemicals. Table 7-2 shows the variety of biofuel types that can be produced.

Table 7-2: Summary of Potential Fuel Types Produced From Biomass

Biofuel Type	Ways to Use with Transport Fuels	Woody Biomass as Feedstock?
Hydrocarbons	*Drop in fuel*, can be used in blends or as replacement fuel	*Uses wood directly*
Ethanol	• Blends of up to 10% with petrol - this already occurs in Australia • Use in blends up to 100% in specialised engines	Generally via sugar but can use *wood directly* or after conversion to sugars
Methanol	• Blends with petrol • *Upgrade to hydrocarbon fuels* • Use directly in specialised engines	*Uses wood directly*
Dimethyl ether	• Blend with diesel or replace it in modified engines • *Upgrade to hydrocarbon fuels*	*Uses wood directly* with methanol as intermediate step
Butanol	• Blends with petrol – limited use in USA • Use in blends up to 100% in specialised engines • *Upgrade to hydrocarbon fuels*	Need to convert biomass to sugars
Farnesene	Upgrade to fuel suitable for blends with diesel	Need to convert biomass to sugars
Biodiesel	• Blends with diesel - already occurs in Australia • Upgrade to hydrocarbon diesel - already used in Australia	Made from oils and fats, no biomass use

Although biofuels have been available for many years, the Australian motoring community has not accepted ethanol and biodiesel blends to the same extent as motorists in Europe and the Americas, suggesting an added barrier to the uptake of ethanol blends in Tasmania.

At December 2013, after more than ten years of federal subsidies for fuel ethanol use, Australian production capacity for fuel ethanol was 440 million litres/year, which represents approximately 2% of the national market for petrol. NSW has mandated ethanol use for several years to encourage the uptake of ethanol-petrol blended fuels. However, even with an ethanol mandate NSW has not maintained growth in ethanol demand, with sales peaking at 4% (petrol replacement) in 2012, then declining to less than 3.5% by September 2014. After some consideration, Queensland has introduced a mandate for 2% ethanol use in its petrol (with the figure of 2% reflecting partial uptake of ethanol as a 10% blend in petrol). Reaching a 2% market penetration for ethanol as a replacement for petrol in Tasmania would require just seven million litres/ year of ethanol, which is too small to justify even a single commercial wood-to-ethanol plant.

While the blending of ethanol and diesel has been demonstrated as being technically feasible with the addition of emulsifiers, it is not practiced commercially anywhere in the world. There is some use of methanol as a fuel, particularly in China where methanol is made from coal and is used in blends with petrol or as a fuel in its own right.

DME and upgraded farnesenes are being used in commercial trials in Sweden and Brazil respectively. Butanol has also been the subject of trials in blends with petrol and jet fuel. However there is no widespread commercial use of any of these fuels yet and there is no natural advantage to the development of these technologies in Tasmania.

Outlook for Transport Fuel Demand in Australia

> The case for “Drop in” biofuels
>
> The widespread use of any biofuel is predicated on its ability to be used successfully by customers in their engines. These range from the petrol and diesel engines in domestic vehicles, through to diesel engines used by the agriculture and mining sectors, to the heavy-duty engines and turbines found in rail, aviation and marine applications. In every case, engine suppliers are expected to guarantee the performance of existing and new engines and turbines when using biofuels.
>
> Ethanol and biodiesel have different physical and chemical properties to petrol and diesel. Their use is therefore based on blending them with petrol and diesel derived from crude oil, with the blend limited to ensure that the resulting fuel characteristics fall within the engine manufacturer’s guidelines. Because of this, the use of such biofuels in blends limits the markets for those biofuels. For example, ethanol use is generally limited to a 10% petrol blend in unmodified engines.
>
> “Drop in” biofuels are designed to avoid this limitation. Such biofuels are renewable hydrocarbons and are made to be almost indistinguishable from petrol, diesel and aviation fuels derived from crude oil. As such they will be capable of being blended with, or completely replacing the equivalent fossil fuels without any adverse impact on engine performance. This provides two major advantages to drop in biofuels:
>
> - A much greater market than ethanol or biodiesel
> - Greater consumer acceptance.

Fuel prices in Australia will continue to be determined by international oil prices for the foreseeable future. Figure 7-3 shows a 10-year average price of just above USD85/ barrel for crude oil. This is significantly lower than the price of more than USD100/ barrel that occurred for much of 2014. Predictions for crude oil pricing to 2020 and beyond reflect a significant element of uncertainty:

- The medium term oil market report released in February 2015 by the International Energy Agency suggests a crude oil price of USD73/ barrel in 2020, down from the figure of USD87/ barrel that was suggested in their June 2014 report.
- The Annual Energy Outlook of the US Department of Energy (published in April 2015) shows a reference (base) case for crude oil reaching USD141/ barrel in 2040. But it also shows substantial variation, with different modelling assumptions yielding a crude oil price in 2040 that varies between USD76 and USD252/ barrel.

While current forecasts suggest some softness in oil price, they are nearly unanimous in predicting increasing oil prices over time as low cost sources of supply decline or are exhausted. Future variation of the crude oil price will impact on the competitive position for biofuels with an increasing oil price positive for biofuel development.

The use of any of the non-hydrocarbon biofuel blends shown in Table 7-2 in low level blends with mineral petrol and diesel would mean that only a small part of the Tasmanian transport fuel market would be met with biofuels. With the exception of ethanol, there is no precedent in Australia and very little precedent in the rest of the world for such blends. One of the key drawbacks is that with every blend, a separate wholesale and retail infrastructure would be required. Finally, if a blend other than ethanol is used, a new set of fuel standards will be needed.

“Drop in” hydrocarbon biofuels are intended to be completely interchangeable with existing petrol and diesel and comply with the relevant quality standards for those fuels. As such, their theoretical maximum market in Tasmania is virtually the total transport fuel use in the state. As Table 7-1 indicates, this is a market of some 850 million litres/year, approximately twenty times the market for a 10% blend of ethanol in Tasmania’s petrol, which is 10% of 363 million litres/year or just 36 million litres/year.

Of all the biofuels, only drop in hydrocarbons offer a combination of large local market and relative ease of use for general customer acceptance. There is currently no widespread use of such biofuels commercially, but precedents do exist:

- Large scale coal-to-liquids plants operate in South Africa and China and natural gas-to-liquids plants operate in South Africa, Malaysia and Qatar. In these plants, hydrocarbon transport fuels are made via the Fischer Tropsch process and the methanol-to-gasoline process. Several different "drop in" biofuel technologies under development also use either the Fischer Tropsch process or methanol conversion in their pathway from biomass to biofuel;
- In Finland, hydrocarbon biofuel is made from tall oil, a by-product of the chemical pulping process. These fuels have been tested extensively and are available in retail markets[47]; and
- Hydrocarbon biofuels made from wood at the Carbona-Haldor Topsoe demonstration plant in the US have been used in more than 100,000km of road trials to date.

7.3 Technology and Proponents for the Production of Drop-in Hydrocarbons

The main pathways for advanced biofuel production are summarised in Figure 7-5. Of particular relevance in a Tasmanian context are the three processes used to produce hydrocarbon liquids from biomass. The hydrolysis pathway leads to ethanol, not hydrocarbon liquids and is typically associated with crop residues rather than woody biomass.

- **Gasification** – wood is gasified to create a combustible gas which is further processed to make a synthesis gas or "syngas", rich in carbon monoxide and hydrogen. Syngas from biomass is similar in many respects to syngas made from natural gas, or from the gasification of coal.
- **Fast pyrolysis** – involves rapid heating of biomass in the absence of oxygen which breaks the biomass into solid, liquid and gaseous fractions. The main product from fast pyrolysis is a liquid. Depending on the process and the biomass used, liquid products can represent 70% or more of the biomass feed. The balance of the feed is converted into charcoal and combustible gas.
- **Hydrothermal liquefaction** - uses supercritical water (water under intense heat and pressure) to break down the carbon-oxygen linkages in pulverised biomass[48]. This process creates a bio-crude material that may then be transported to existing oil refineries where it is blended with traditional crude oil and refined to produce transport fuels.

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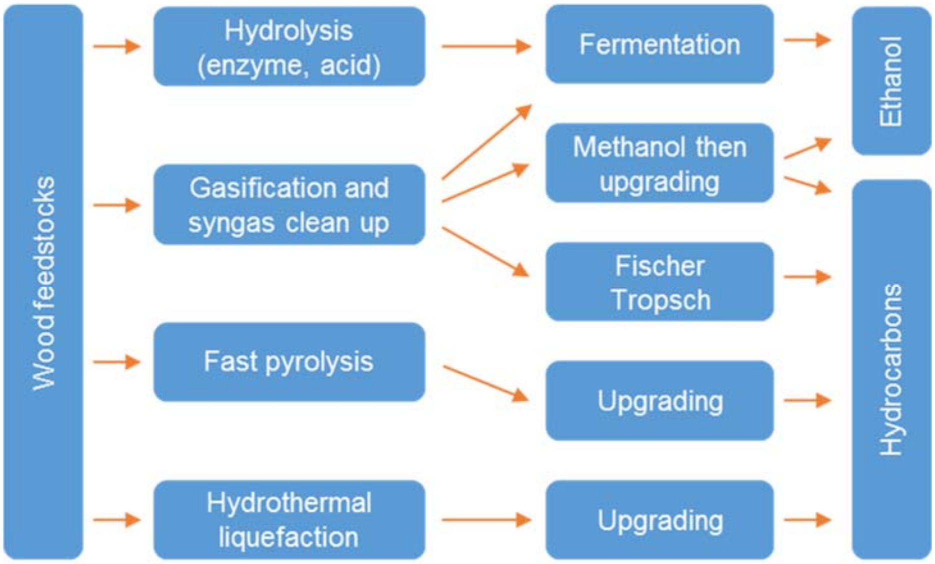
[47]http://www.upmbiofuels.com/renewable-diesel-upm-bioverno/upm-bioverno-is-compatible-with-all-diesel-engines/Pages/default.aspx

[48] http://www.licella.com.au/about-us/our-technology.html

Figure 7-5: Schematic Showing Pathways for Biofuel Production



Gasification

At this time there are no commercial-scale plants using gasification of biomass to make hydrocarbon liquid fuels, either in operation or under construction. However, as Table 7-3 shows, a lot of development work is underway internationally by dedicated organisations and also within large conglomerates.

Table 7-3 shows a broad range of projects are being developed internationally, primarily in Europe and the US. A number of these developments are contingent on policy support through fuel mandates and grants. As a result of policy uncertainty, some of these projects are currently on hold pending confirmation of ongoing support.

The by-products produced from gasification depend on the technology used. The Fischer Tropsch process produces a wide range of hydrocarbon by-products from light ends (methane type gas) through to heavy products such as bitumen. Other process pathways such as the TIGAS or Mobil processes produce fewer by-products.

Table 7-3: Current Status of Biofuel Development Using Biomass Gasification Technology

Proponent(s)	Technology Pathway	Scale
Andritz Carbona & Haldor Topsoe	Gasification then TIGAS to gasoline blendstock	Integrated demonstration plant operated in USA during 2014. More than 100,000km of road trials for fuel
Total, IFPEn, Thyssen Krupp and others	Torrefaction, gasification then FT process	3 t/hour integrated demonstration project now being built in France at total cost of more than AUD150 million[49]. Target is commercial plant by 2020, to make 200,000 t/year fuel from 1 million t/year biomass.
Fulcrum Bioenergy	Gasification then FT	Municipal solid waste (MSW) to jet fuel - USD266M plant in Nevada to make 42 million litres/year jet fuel. Received US Gov't loan guarantee for USD105 million in Sept 2014.
KIT & Air Liquide "Bioliq" process	Gasification of pyrolysis oil then DME and fuel synthesis[50]	Pilot plant at Karlsruhe Institute of Technology (KIT) 500 kg/hour pyrolysis and 1 t/hour gasification. AUD100 million project achieved integrated operation in second half of 2014[51].
UPM Stracel	Carbona GTI gasifier	Proposed a commercial plant to use 1 million t/year of wood. On hold as of 2014, citing uncertainty of EU policy support.
Forest BTL	Linde (Choren) gasifier then FT	Proposed a commercial plant at Ajos in Finland to use 1 million t/year of wood and make 115,000 t/year fuel. On hold as of 2014, citing uncertainty of EU policy support.
NSE Biofuels (Neste & Stora Enso)	Gasification then biofuel production (with Foster Wheeler and VTT)	Demo gasifier operated but, in the absence of ongoing government funding assistance, the partners announced in 2012 and that no follow on work was planned[52].
Enerkem	Gasification and methanol synthesis.	Commercial waste to methanol in Canada, using refuse derived fuel. Wood feed also successfully trialled in demo facility. Enerkem's methanol not yet linked to hydrocarbon production pathway.
Solena	Plasma gasification of MSW. Gas cleaning and preparation. FT with Velocys technology then liquid separation	No integrated demonstration yet. First commercial UK site announced in 2014, to process 600,000 t/year of refuse derived fuel.
Red Rock Biofuels	Unknown gasification and gas cleaning technologies. Velocys for FT technology	No data on trials or technology other than link to Velocys. 50 million litre/year plant proposed for Lakeview, Oregon this year, at a cost of USD200 million and with a USD70 million government grant.
Sundrop fuels	Uhde gasifier and methanol to gasoline	15,000 barrel/day facility in Louisiana, using natural gas and some biomass. No recent announcements.

Fast Pyrolysis

Many groups around the world have demonstrated fast pyrolysis at various scales using a range of technologies to heat the biomass[53]. Some research groups have experienced difficulty in making stable, single phase oil, leading to a misconception that such is always the case. Canadian companies Enysn and Dynamotive both demonstrated that large-scale pyrolysis is achievable and that stable, high quality pyrolysis oil can be produced. Ensyn's earliest plants

[49] http://www.total.com/en/energies-expertise/renewable-energies/biomass/projects-and-achievements/biotfuel-project-produce-biofuels-thermochemical-conversion?%FFbw=kludge1%FF

[50] http://www.bioliq.de/english/55.php

[51] http://www.bioliq.de/english/60_207.php

[52] http://www.biofuelstp.eu/btl.html

[53] Bridgwater, A. V. (2012). Review of fast pyrolysis of biomass and product upgrading. *Biomass and Bioenergy*, *38*, 68–94.

have operated for more than twenty years. Dynamotive has used its raw pyrolysis oil to drive a gas turbine to demonstrate its quality.

The major global commercial fast pyrolysis initiatives are summarised in Table 7-4.

Table 7-4: Current Status of Biofuel Development Using Fast Pyrolosis Technology

Company	Scale of Pyrolysis	Upgrading to Liquid Transport Fuels	Commercial Status
Ensyn - Canada	75 t/day at Renfrew, Ontario. Several smaller plants in USA operating for up to twenty years or more.	Joint venture with UOP. Propose adding pyrolysis oil to FCC feed at up to 5% for refinery co-processing[54].	Commercial pyrolysis operational for many years. Commercial co-processing in oil refinery expected in next few years.
Dynamotive – Canada	130 and 200 t/day plants built in Ontario, Canada.	Joint venture with IFPEn (France) to commercialise upgrading technology.	Pyrolysis already commercial using sawmill residues and construction wood residues, but capable of using a wide range of feedstocks. Upgrading step expected to be commercial before 2020.
BTG - the Netherlands	120 t/day fluid bed plant built in Canada for site in the Netherlands. Officially opened May 2015	Shell has showed that FCC and DSU co-processing (up to 20% hydro-deoxygenated bio-oil) is feasible. BIOCOUP lab work with VTT to 2011. Economic analysis showed competitive gasoline.	Not published
Metso & VTT - Finland	150 t/day plant integrated with power station. Commissioned Nov 2013.	LignoCAT program, with Fortum, UPM, Valmet– 5 year program announced in 2014 funded by Finnish gov't	Not published but utilises forest residues and other biomass
KiOR - USA	500 t/day plant operated in USA	Commercial upgrading facility built, but shut down in 2014 before yield targets were met due to financial constraints.	2013 for commercial prototype using local roundwood. That plant was subsequently shut down, pending improved catalyst performance.
Lurgi - Germany	Bioliq - twin screw unit at pilot plant scale in Germany	Pyrolysis oil to be fed to gasifier then syngas used for FT synthesis.	Not clear
Cool Planet	Pilot plant operated in California, USA.	"Drop in" fuels produced as part of process	Commercial-scale plant under construction in Louisiana, US, using softwood chip, targeting initial operation in 2016.

A commercial opportunity for fast pyrolysis and upgrading was examined in a recent Australian study, funded by Airbus and conducted by the CRC for Future Farm Industries. The study considered the use of Dynamotive/IFPEn technologies in Western Australia to convert plantation mallee eucalypts into jet fuel for use by Virgin Australia and ground transport fuels to replace petrol and diesel. The study noted that 120,000 dry tonne/year of wood feed could be converted into 40 million litres/year of transport fuel, plus a range of green chemicals.

This feasibility work identified the large-scale, "triple bottom line" benefits (commercial, environmental, social) that could be achieved if wood to biofuel plants are built in rural locations. The study report also described the ongoing project development work to be undertaken if Australia is to achieve the timely use of the various biofuel technologies that are now being commercialised overseas. This work includes further refinement of biomass supply chains and the detailed development of the commercial business case for a specific biofuel plant investment.

[54] http://www.ensyn.com/products/fuel-products/refinery-coprocessing/

Charcoal is also produced during fast pyrolysis and depending on the pyrolysis process, the charcoal may be used on site for energy or made available as a co-product. Charcoal made by Dynamotive and Cool Planet has been used successfully in tests as biochar for soil enhancement. This raises the potential for creating large quantities of biochar with the possibility that it can be produced cheaply as a co-product of large-scale biofuel production, rather than as the principal product of small slow pyrolysis plants.

Hydrothermal Liquefaction

This approach has been developed by groups in Australia and overseas but is still largely at a demonstration level of development:

- Licella's process to make bio-crude has been demonstrated in its three tonne/day pilot plant in NSW. The company has recently built a larger demonstration facility and, with federal government funding support, is now developing preliminary engineering and an investment case for a pre-commercial plant capable of making bio-crude from processing 50,000 tonnes/year of pulverised feed (measured on oven dry basis). Licella advises that four such modules, processing 200,000 dry tonnes/year of biomass, could share a centralised upgrading facility that produces 45 million litres/year of transport fuels and a range of chemical precursors.
- Steeper Energy is a company working in Denmark and Canada. It has demonstrated its hydrothermal technology at laboratory scale and is currently working towards a 100 barrel/day demonstration-scale plant in Canada with Canadian Government support. The company is also investigating a full-scale plant to make sulphur-free marine fuels in Denmark.
- Altaca Environmental Technologies and Energy is commercialising the "CatLiq" process, which was originally developed in Denmark. Laboratory and pilot-scale plants have been built and operated, and construction of a first commercial plant was due to begin in Turkey during 2014.

Information on the byproducts created from the hydrothermal liquefaction process are not in the public domain.

Biorefining (Upgrading Bio-crudes)

The thermochemical processes of gasification, pyrolysis and hydrothermal liquefaction all lead to intermediate liquid fuels (bio-crudes) that require further processing (upgrading) to make finished transport fuels. The upgrading can occur at:

- **An existing oil refinery**. This approach has the benefit of utilising existing plant (and thus avoiding capital expense) and processing biofuels alongside liquids derived from crude oil. As Tasmania has no oil refineries this approach could represent a substantial barrier to further development of processes where bio-crudes require co-processing; or
- **The same location as the thermochemical process**. This is already the case for large scale coal and natural gas to liquids plants using Fischer Tropsch or Mobil processes. This approach requires additional capital expense over oil refinery co-processing, but may be the only alternative in the absence of a suitable existing oil refinery; or
- **A dedicated, centralised upgrading plant**. It is possible to make bio-crude close to the source of biomass and transport that crude to a centralised upgrading facility, which may receive bio-crude from several plants and perform a regional upgrading function.

In addition to producing transport fuels, a biorefinery could potentially produce a range of other end products. Oil refineries typically manufacture of a range of materials, including plastics feedstocks, fuels for motor vehicles, heavy fuels for heating and ships, and bitumen for road-making. In this way the productive use of the crude oil is maximised, which enhances the commercial viability of the refinery. A biorefinery could use bio-based materials in a similar way, with multiple products produced to enhance the refinery's commercial viability. This extension to the fuel manufacturing process could be a logical progression for many biofuel plants.

Whatever the refining process, it would need to upgrade fuels to meet the relevant fuel standards. The Australian fuel standards have been developed to set pollutant thresholds in vehicle emissions and control chemicals that can have an adverse impact on the efficient engine operation and the environment. Fuel specifications have been developed for hydrocarbon biofuels in the US and Europe. Meeting these fuel standards does not appear to represent a material barrier to date as a number of renewable fuels have been extensively tested at a demonstration scale in ground transport, aviation and marine applications.

There are many different approaches to the upgrading process, each with its own equipment needs and associated costs. The crude oil refining industry in Australia is in decline. In the 1970s Australia had nine operating oil refineries but the number has reduced to just four in 2015. Of the four remaining operational units, one recently avoided closure via a sale to a new operator. This decline is largely because of the age and size of the Australian refineries; they are older, smaller and less cost-efficient than the new refineries being built in Asia, where an increasing proportion of Australia's transport fuels are sourced from.

Tasmanian bio-crude could be transported to Victoria for co-processing alongside crude oil in an existing Victorian oil refinery. Canadian fast pyrolysis company Ensyn suggests a co-processing throughput rate of 5% of refinery capacity which would be equivalent to approximately 250 million litres of biofuel per year for a Victorian oil refinery. However ,this approach will incur extra transport costs and there is a risk that the Victorian refinery will close because of cost issues which are outside the control of any bio-crude supplier. This is a significant risk factor given the status of Australia's current refining capacity.

The alternative is to build and operate dedicated biorefineries in Tasmania. This approach is expected to have a higher capital cost than co-processing, but it facilitates the use of biofuels directly in the Tasmanian market and avoids the risk associated with offshore co-processing in an existing oil refinery.

There is no fixed size for a biorefinery; for example, a first Tasmanian biorefinery may be small (e.g. 100 million litres/year of transport fuels) to establish the industry and subsequent biorefineries larger to capture economies of scale. Several biorefineries could be built over time and by different proponents as the Tasmanian biofuel industry grows.

7.4 Social and Environmental Considerations

Environment

Globally, a total of sixty-four countries now have targets or mandates for renewable transport fuels (ethanol and biodiesel). The bulk of mandates continue to come from the EU-27, where the Renewable Energy Directive (RED) specifies a 10 percent renewable content by 2020, with a proportion coming from advanced biofuels[55]. In the Americas 13 countries have mandates or targets in place or under consideration, 12 in Asia-Pacific, 11 in the Africa/ Indian Ocean region and 2 from non-EU countries in Europe[56]. This indicates strong policy support globally for the continued development of renewable fuels.

Advanced biofuels produced from woody residues can be produced at a large scale without displacing land or crops used for food production, a major concern associated with first generation biofuels. The manufacturing process breaks woody material down into its cellular components. This means a wide range of feedstocks can potentially be utilised for the manufacture of biofuels, including residues sourced from native forests.

[55] http://biofuelstp.eu/biofuels-legislation.html

[56] http://www.biofuelsdigest.com/bdigest/2014/12/31/biofuels-mandates-around-the-world-2015/

Widespread utilisation of biofuels would have a material impact on GHG emissions across the transport fuel supply chain. Carbon emissions would be reduced through:

- The displacement of fossil fuels by a renewable fuel. This would be further enhanced if harvesting and transport operations in Tasmania were converted to biofuels;
- Reduced overall fuel consumption with a much shorter supply chain based on a domestic rather than international resource; and
- Potential to expand carbon sequestration through forest expansion.

Knight (2015)[57] reported an estimated 73.7% reduction in GHG life-cycle emissions for renewable fuels compared to conventional petrol.

The emissions from a hydrocarbon biofuel plant will depend in part on the technology selected. Typically some combustion takes place to create heat for initial processing and subsequent distillations. The only addition to the bio-crude during the fuel upgrading process is hydrogen, which is typically derived from natural gas or water. No hazardous solid or liquid wastes are required during the process. Some of the key inputs and outputs to the process are summarised in Table 7-5.

Table 7-5: Key Inputs/Outputs From the Biofuel Production Process

Inputs	Stage	Requirement
Energy	Residue processing	Energy for residue processing is required for size reduction of wood fibres (non-recoverable) and moisture removal (potential from surplus heating other parts of the process) prior to processing. Some energy may be required for distillation of end products. Much of this energy can be recovered
Chemicals	Upgrading	Hydrogen sourced from natural gas or water. No hazardous or toxic materials required during the manufacturing process
Outputs		
Fuel	End product	Classified as a hazardous substance but no different requirements to existing fuel handling regulations
Emissions	Processing and upgrading	Emissions similar to other combustion plants that routinely meet EPA requirements in Australia and overseas
Water runoff	Yard storage	Depends on process but runoff management no different to other bulk wood storage facilities
Process water	Upgrading	Water produced through fast pyrolysis process requires treatment before being reused or discharged
Byproducts		Charcoal – potential to use as biochar

The fast pyrolysis plants already operating in North America have generally been located alongside existing sawmills and in full compliance with the requirements of the US and Canadian EPAs. A commercial fast pyrolysis plant recently installed in Europe is shown in Figure 7-6 to provide an example of the scale and physical impact of these plants. This facility has the capacity to process approximately 120 tonnes/day of dry biomass (~85,000 green tonnes/year of green biomass).

57 Knight, R (2015) Green Gasoline from Wood Using Carbona Gasification and Topsoe TIGAS Processes, DOE Bioenergy Technologies Office (BETO) 2015 Project Peer Review

Figure 7-6: Empyro Fast Pyrolysis Plant in The Netherlands

Source: Enecon

The impact of moving and stockpiling large volumes of wood could to some extent be mitigated through the development of multiple smaller scale thermochemical plants that process the residues to produce bio-crude. To minimise processing costs, these plants would be located close to the fibre source and have a structure similar to that shown in Figure 7-6. The bio-crude produced from these plants would then be transported to a central facility for upgrading.

Refineries are typically large scale operations. For example, the Exxon Mobil refinery in Altona, Victoria supplies half of Victoria's fuel needs producing up to 13 million litres of refined products per day or over 4.5 billion litres on an annualised basis. By comparison, assuming biofuels could displace 100% of Tasmanian petrol and diesel demand, the maximum size for a single Tasmanian biorefinery would be approximately 750 million litres/year, substantially smaller than the Altona refinery, which occupies a site of approximately 10 hectares.

Refineries are typically located close to the areas of demand. The Altona refinery is located on the urban fringe of western Melbourne with residential and light industrial properties situated adjacent to the refinery. The location of a bio-refinery would depend on how it integrates with the existing fuel distribution infrastructure. If biofuels are to be pumped into the existing fuel storage network, its location would need to allow efficient pumping from the refinery to the tank farm. A greenfields tank storage farm is another possibility. As the fuel would be for domestic consumption, the location of any new tank farm does not have to be adjacent to any of the three existing fuel storage ports.

Any new large-scale biorefinery/ tank storage development would represent a major piece of infrastructure and would require studies of its environmental impacts as well as health and safety risks as part of the permitting process. Tasmania does not have any existing refinery capacity so the environment regulations to manage this process would need to be developed.

Social

Domestically produced hydrocarbon biofuels would improve fuel supply security and reduce reliance on fuel oil imports, an issue already raised in the Tasmanian Energy Strategy[58].

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[58] Tasmanian Energy Strategy – Restoring Tasmania's Energy Advantage. Department of State Growth, May 2015

A US report consolidated data estimating job creation and economic output associated with the development of an advanced biofuels industry in the US[59]. The multipliers for job creation and economic development are similar to those used in a recent study for a biorefining industry in Queensland[60]. The study identified the potential for an additional 6 640 full time equivalent roles through direct, indirect and induced activities associated with biorefining as well as an additional AUD1.9 billion/year in related economic output.

7.5 Prospects for Drop in Hydrocarbon Production in Tasmania

Drop-in hydrocarbon biofuels represent a prospective long-term option for Tasmania because:

- Domestic production would reduce reliance on imported fuels and improve Tasmania's trade balance;
- The production process doesn't replace existing Tasmanian production (i.e. Tasmania does not have an existing oil refinery);
- Tasmania pays more for its fuel than other parts of Australia and therefore has a greater capacity to pay for biofuel;
- Market demand for transport fuels is stable and well defined;
- The process could potentially consume large amounts of biomass residues and could be flexible with the type of feedstock used;
- Hydrocarbon biofuels can be used interchangeably with existing fuels derived from crude oil and could utilise the state's existing fuel infrastructure; and
- Carbon emissions would be reduced as fossil fuels consumed in Tasmania and through the crude oil supply chain would be displaced by a renewable fuel.

End Markets and Feedstock Availability

The market for drop-in hydrocarbon biofuels in Tasmania would be the displacement of existing oil-based transport fuels (specifically petrol, diesel and jet fuel) which is some 750 million litres/ year. Using an average conversion efficiency of 300 litres of hydrocarbon fuel/ dry tonne of biomass, meeting the total Tasmanian market with biofuels would require the supply of 2.5 million dry tonnes/ year of biomass, or some five million green tonnes (assuming 50% moisture content on a green or 'wet' basis)/ year. Meeting just a part of the Tasmanian fuel demand would result in correspondingly lower use of biomass residues.

Gasification, fast pyrolysis and hydrothermal liquefaction all use heat to break down the structure of the wood prior to biofuel manufacture. These processes are capable of processing a wide range of woody feedstock so co-processing of hardwood and softwood residues should be possible. Use of some leaf and bark material is also possible.

In all cases the wood fibre must be reduced to a particle size suitable for a fast, consistent reaction. This may range from wood chips to fine particles. With gasification and pyrolysis, most of the water in the wood should be removed before processing.

Figure 7-7 shows the regional distribution of forest residues by type and processing residue by source. Other Stemwood is included in the volume data as it could potentially be used as a feedstock provided it was economic to do so. Collectively there is in excess of five million green tonnes available when timber processing, plantation and native forest resources are considered.

The Murchison and Bass regions contain the greatest residue volume with hardwood pulpwood plantations representing the single greatest source of supply. The Derwent and Mersey regions

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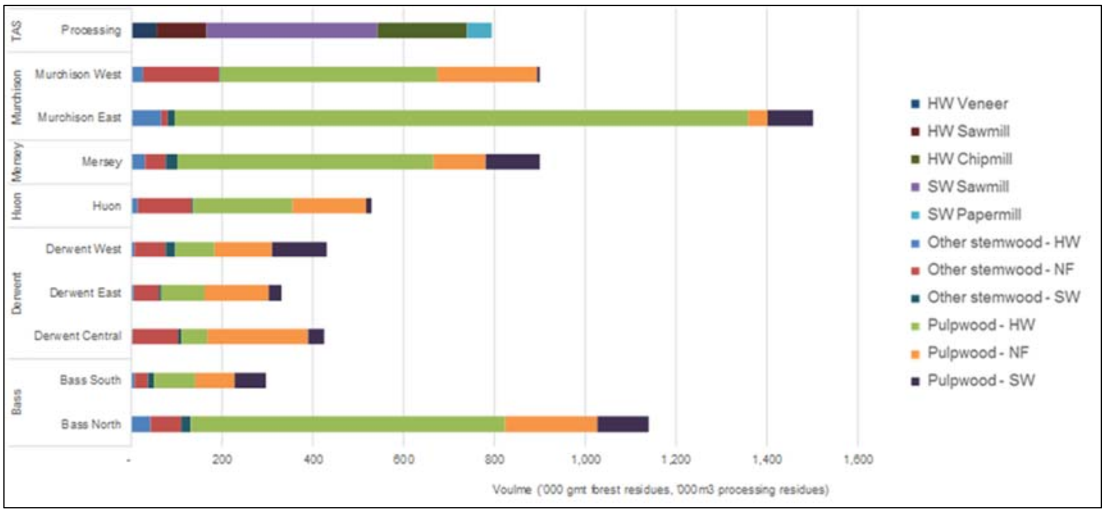
[59] US economic impact of advanced biofuels production: perspectives to 2030. Bio-economic Research Associates, February 2009

[60] Economic impact of a future tropical biorefinery industry in Queensland. Deloitte Access Economics & Corelli Bio-industry Consulting, 2014

also contain substantial volumes with close to one million tonnes of forest residues available. The Huon region has the least volume, but still has the capacity to supply over 500,000 tonnes/year of residues.

Figure 7-7: Regional Distribution of Residue Availability in Tasmania



Source: FT, PFT, NCFFI (unpubl.)

The most likely biofuel industry infrastructure would involve the supply of biomass feedstock to a number of thermochemical plants where bio-crude would be produced. The thermochemical plants would be located close to the biomass source to minimise delivered fibre costs.

The scale of any thermochemical plant would be determined by the amount of biomass that could be delivered cost-effectively to the plant. As such, prospective locations would need to consider the range of feedstocks available and the delivered cost for each residue type.

The bio-crude produced at each thermochemical plant could then be transported to a centralised biorefinery for upgrading to biofuels. A new, standalone upgrading facility will mimic part of a conventional oil refinery. The actual configuration (and cost) will be influenced by the nature of the biofuel intermediate to be upgraded as some bio crudes may require significantly more processing than others to produce finished fuels. Also, some biofuel intermediates can be upgraded to almost 100% transport fuels while others may produce a broader range of hydrocarbon products. This can influence the complexity and cost of the upgrading facility as well as the commercial viability of the proposed business.

Centralised upgrading facilities can offer some economies of scale if they process the bio-crude from a number of thermochemical plants. For example, in Tasmania this might mean two centralised upgrading facilities, each producing up to several hundred million litres per year of finished fuels. One might be located in the north of the state and the second located in the south. The upgraded fuels would then be distributed directly to wholesalers or retailers.

As noted earlier in this section a ‘small’ biorefinery might produce around 100 million litres of biofuel annually. This equates to a woody residue requirement of around 650,000 green tonnes/ year. As the scale of production expands, so does the complexity the supply chain. A larger facility producing 400 million litres/year would require over 2.5 million green tonnes of biomass annually, although the supply of residues would be spread over a number of thermochemical plants.

At this scale, supply agreements would be required with major processors/ growers as no single sub-region would have the capacity to supply all of the feedstock. Biofuels would also represent a dominant source of market demand for residues in Tasmania which may limit the market options available to growers for the sale of residue material.

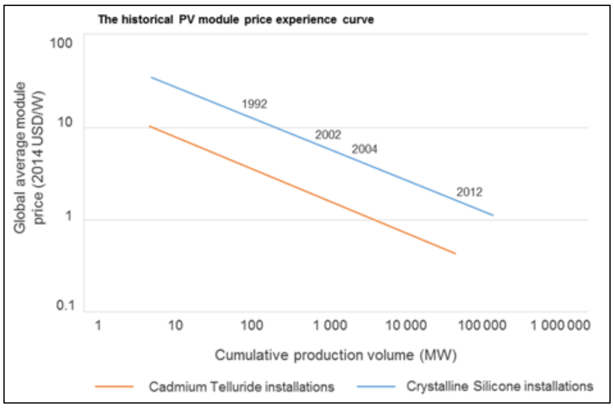
Economic Considerations

International efforts have focused on the development of advanced biofuels for a number of years. As a consequence the technology has reached the early commercial phase with a number of technology providers offering proprietary techniques for the bulk production of biofuels. The most likely route to commercialization is for these proponents to license their technology. This implies that the establishment of a biofuel sector in Tasmania can be based on commercial designs supported by global experts that have already spent hundreds of millions of dollars. Such an approach can avoid the need for local technology R&D or development and save both time and money. Some of the key benefits for Tasmania from this approach include: lower development costs; lower risk as engineering and process issues have already been resolved, and projects become easier to finance as there are international precedents.

Technologies for production of ethanol and biodiesel from sugars, oils and fats are relatively mature, and further major cost reductions are not expected. In contrast, the hydrocarbon biofuel industry is still in its infancy, and significant cost (capital and operating) reductions are expected as initial plants are built and the experience gained is incorporated into subsequent plants. Such cost reductions are common to all technologies as they progress from the early commercial stage through to maturity and widespread use. As Figure 7-8 demonstrates, this phenomenon is apparent in both the solar energy (LHS) and wind industries (RHS) when considered over a long timeframe. This trend is also commonplace in the chemical and metallurgical process industries.

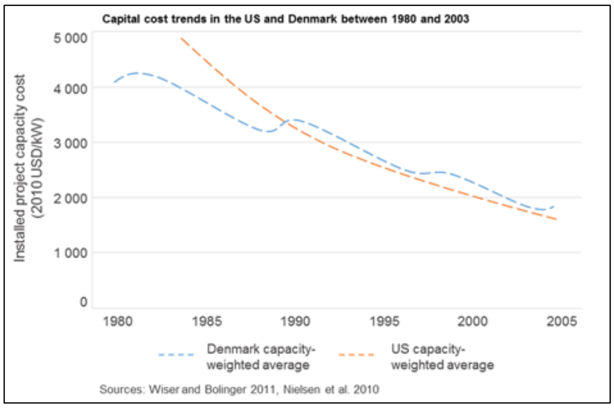
Figure 7-8: Long-Term Production Cost Trends for Wind and Solar Power Production

Solar Power



Adapted from: International Renewable Energy Agency

Wind Power

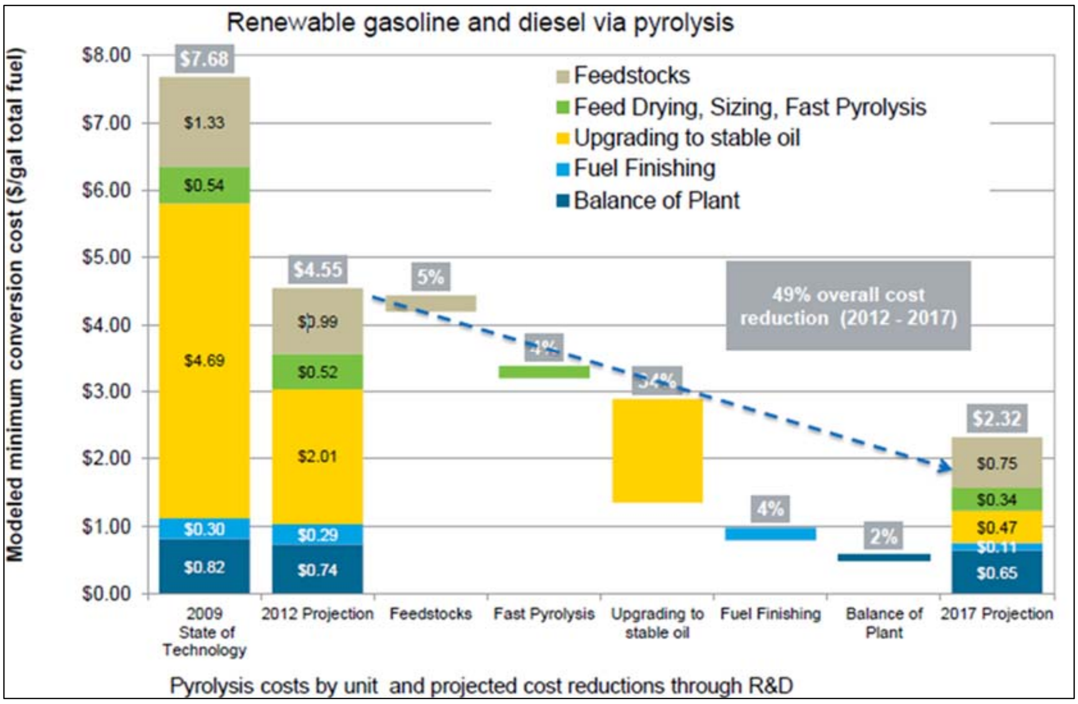


Adapted from: IEA Task26

Significant cost improvements are also expected within the advanced biofuels industry. For example, Figure 7-9 shows work by the US Department of Energy[61] which estimates potential cost reductions totalling 49% may be possible over a five year period for biofuels made via fast pyrolysis as the technology matures.

[61] Haq Z. Biofuels design cases. DOE Office of Biomass Program, 24 April 2012

Figure 7-9: Summary of Projected Costs for Fast Pyrolysis Biofuels



Source: US Department of Energy

Incentives

Australia provides a number of financial incentives for ethanol and biodiesel. Australian government support for ethanol and biodiesel has already operated for a number of years, and was revised in the 2014 federal budget:

- Prior to 30 June 2015, fuel ethanol production was supported by the Ethanol Production Grants Programme. On 1 July 2015 fuel excise on domestically produced ethanol reduced to zero and it will then increase by 2.5 cents/ litre each year for five years from 1 July 2016[62]. If this scheme is maintained it will cap ethanol excise at 12.5 cents/ litre. By comparison, fuel excise is currently 38.6 cents/ litre and subject to bi-annual reviews in February and August of each year[63].
- Prior to 30 June 2015, biodiesel and renewable diesel were supported by the Cleaner Fuels Grants Scheme. This scheme finished on 30 June 2015, and excise on these fuels was to zero on 1 July 2015. From 1 July 2016, the excise rate for biodiesel will be increased for five years until it reaches 50 per cent of the energy content equivalent tax rate. The excise equivalent customs duty for imported biodiesel will continue to be taxed at the full energy content equivalent tax rate[64].
- There is also scope for drop-in hydrocarbons to participate in the Carbon Farming Initiative as there should be net carbon gains from the replacement of fossil fuels with renewable fuels. The existing methodology for Land and Sea Transport and Air Transport contain provisions for project proponents to claim carbon credits where carbon abatement occurs through a change of energy sources.

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[62] https://www.ato.gov.au/Business/Excise-and-excise-equivalent-goods/In-detail/Fuel/Fuel-ethanol/Excise-on-fuel-ethanol/
[63] https://www.ato.gov.au/General/New-legislation/In-detail/Indirect-taxes/Excise/Reintroduction-of-fuel-excise-indexation/
[64] Page 218 - http://www.budget.gov.au/2014-15/content/bp2/download/BP2_consolidated.pdf

Hypothetical Capacity to Pay Analysis

Retail and wholesale fuel pricing

At the start of August 2015, the retail price for petrol in Hobart was AUD1.43 per litre[65]. The composition of the retail price is summarised in Table 7-6. There is limited evidence to suggest consumers would pay extra for biofuels therefore the retail sale price is assumed to be the same as for petrol. It is also assumed the fuel's environmental benefits would be recognised through partial excise tax exemption (as per the situation for biodiesel under the national legislation described previously). This analysis indicates a biofuel wholesale fuel price of AUD0.79 - 0.98/ litre (depending on the excise reduction) would be required to be comparable with the retail price for fuel derived from fossil fuels.

Table 7-6: Comparison of Potential Wholesale Biofuel Price and Current Fuel Prices

Component	Cents/ Litre Fossil Fuel	Cents/ Litre Biofuel
Retail price to consumer at pump	143	143
Less GST	13	13
Less retail costs	13	13
Wholesale cost with excise but not GST	117	117
Excise payable	38	19
Wholesale fuel price or Terminal Gate Price **Hypothetical wholesale fuel price for biofuel**	**79[1]**	**98[2]**

1) Includes crude oil price, refinery costs and transport to Tasmanian fuel terminal
2) Includes purchase of biomass feedstock and local manufacturing costs (as per Table 7-7) plus partial excise reduction as a renewable fuel.

Estimated Biofuel Production Costs

Commercial biofuel technology developers make very little information public about the production costs associated with the manufacture of a drop-in hydrocarbon biofuels. Refinery catalyst experts Haldor Topsoe report that, based on their demonstration work with gasification and the TIGAS process for conversion of syngas to liquid fuels, a production cost of under USD1.00/ litre is expected from their first commercial plant, although feed price is not mentioned in the article.

The US government operates a number of national research laboratories that have interests in biofuels. These organisations have worked for many years with engineering companies and other specialists to develop independent estimates for the costs of advanced biofuel plants based on several different pathways. Biofuel plants may be built to a range of different scales; the US government work has arbitrarily used a plant sized for 2,000 tonne/ day of dry woody biomass feed (equivalent to approximately 1.3 million tonnes/ year of green wood). Estimates also assume that the technology has achieved some maturity (i.e. several plants have been built and operated and this "nth" plant benefits from the design and operational experience).

On this basis:

- A plant to make petrol and diesel via gasification and Fischer Tropsch conversion requires a selling price of USD1.20/ litre based on feed delivered at USD75/ dry short ton. The "pioneer" plant (the first commercial plant to be built) is expected to cost slightly more than double the cost of this nth plant.

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[65] http://www.aip.com.au/pricing/weeklyreport.htm

- Work by the U S government published in 2011 estimated that a plant to make petrol and diesel via gasification and methanol to gasoline technologies would produce petrol at a price of USD0.52/ litre from biomass sourced at USD55.89/ dry tonne.
- A plant to make petrol and diesel via fast pyrolysis and oil upgrading requires a selling price of USD0.90/ litre based on feed delivered at USD80/ dry short ton[66].

The examples above show that a range of pricing is estimated for advanced biofuels, and that in many cases it is expected that, over time, renewable biofuels will become competitive with conventional fossil fuels.

It is possible to use the US government data to develop conceptual costs for biofuels in Tasmania. The fast pyrolysis example above assumes a transport fuel yield of 84 US gallons/ short ton of dry wood feed. This is equivalent to production of 350 litres of fuel per metric tonne of dry wood feed. Based on an exchange rate of AUD0.75:USD, the composition of the manufacturing cost (exclusive of feedstock costs) is shown in Table 7-7.

This analysis indicates that an advanced biofuel could potentially be manufactured for around AUD0.86/ litre, assuming the technology has been successfully commercialised with multiple plants operating. This price represents the wholesale price paid for the biofuel, together with any government subsidy for carbon mitigation (currently this subsidy is provided via rebate of excise tax).

Table 7-7: Hypothetical Manufacturing Costs for Drop-in Biofuel

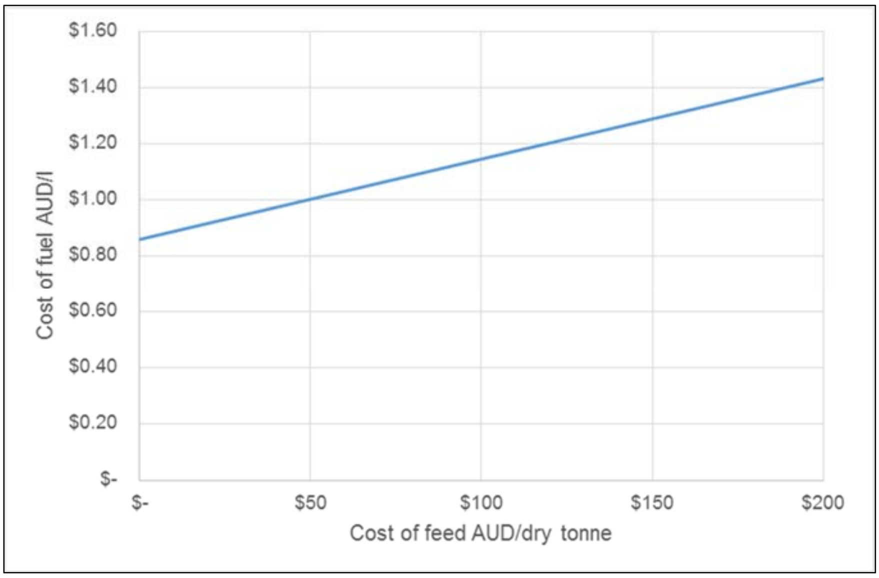
Manufacturing Cost Component	*AUD per Litre of Fuel*	*Proportion of Production Cost*
Natural gas	0.035	4%
Catalysts and chemicals	0.113	13%
Waste disposal	0.004	0%
Electricity & other utilities	0.032	4%
Fixed costs	0.187	22%
Capital depreciation	0.123	14%
Tax	0.035	4%
Return on investment	0.328	38%
Total production cost	**0.857**	**100%**

Source: Interpretation of US Department of Energy data

This data was then extrapolated to show the relationship between feedstock cost (i.e. an indicative capacity to pay) based on the wholesale fuel price, as shown in Figure 7-10.

[66] Process Design and Economics for the Conversion of Lignocellulosic Biomass to Hydrocarbon Fuels - Fast Pyrolysis and Hydrotreating Bio-oil Pathway. PNNL-23053 NREL/TP-5100-61178, November 2013

Figure 7-10: Indicative Capacity to Pay for Biomass based on Wholesale Biofuel Price



Source: Interpretation of US Department of Energy data

To meet the August 2015 pricing for petrol in Hobart it was shown in Table 7-6 that a wholesale price of AUD0.98/ litre would apply to the biofuel (assuming a fuel excise rebate was in place). If biofuel could be sold at that price, Figure 7-10 indicates that the biofuel plant could afford to pay up to an average of AUD50/ dry tonne for biomass.

Were the price for crude oil to increase by approximately 50% by 2020, as suggested by the IEA and US government predictions, the wholesale selling price for biofuel could increase to approximately AUD1.30/ litre and the price payable for feedstock could be in the vicinity of AUD160/ dry tonne.

As the cost of production decreases with experience, the capacity to pay for biomass should increase. A 15% reduction in production costs would translate into a capacity to pay an additional AUD45/ dry tonne for feed. If this was added to a biofuel price of AUD1.30/ litre, then the capacity to pay for feedstock in 2020 would be around AUD205/ dry tonne, comparable to the current market price for hardwood woodchips. The conversion of hardwood woodchips to biofuels within the state, as opposed to export to overseas markets, would create additional jobs and economic activity in Tasmania.

This high level analysis is based on one example, with no allowance made for the relative costs for building the plant in the US or at a different scale in Tasmania. Similarly plant developers may wish to remove risks regarding feedstock pricing and volume, and structure up agreements of a range of differing forms. Nevertheless, it suggests that biofuels could be competitive in the near term with access to low cost residues.

Pricing of advanced biofuels will be driven by international trends in crude oil markets, so the cost of production is a critical element to remain competitive with international fuel prices. This gap represents a key barrier to further development of the biofuel sector.

Pathway for Residue Utilisation

The development of a drop-in hydrocarbon fuel market in Tasmania would be a long process, requiring a significant investment of financial capital by industry, supportive policy frameworks and community engagement by federal and state governments. It can be seen from the preceding sections that a large number of organisations around the world are working towards commercial scale plants for the production of drop-in biofuels from woody biomass. These commercial prototypes de-risk the use of the technologies at large scale, reduce costs through operational experience, and create a more favourable environment for investment in subsequent plants. All are being developed with the aim of replication globally via a range of licensing, partnering and owner-developer models.

There are multiple biofuel technologies at various stages of development and there is currently no single technology that has proven superior to the others. As these technologies develop Tasmania will be able to take advantage of the work by these technology groups so development of a commercial biofuels industry in Tasmania would not require local technology R&D or plant scale-up, with its associated delays and high-risk capital.

Any initial biofuel development in Tasmania would most likely be focused on supplying local markets. One of the reasons Tasmania is attractive from a biofuel perspective is its higher fuel price, which allows a biofuel development more scope to be competitive than elsewhere in Australia. Should a biorefinery be established in other parts of Australia there is the prospect that Tasmania could supply bio-crude, but the additional costs associated with secondary transport and the development of the infrastructure required to establish export ship loading facilities mean it is unlikely to be cost competitive with any local supply that does not have to incur these costs.

Construction of a single, large scale biorefinery would be difficult to justify as there would be long transport distances for the bio-crude and significant underutilisation through the early stages of development which would occur over a number of years. Two or more smaller biorefineries could be constructed as the industry develops. The overall development of multiple units across the state is likely to take a number of years to initiate and then many years to fully implement. It could involve multiple organisations, leading to a competitive production environment and effective use of capital over time. Capital investment is likely to start at several hundred million dollars and could grow to several billion dollars, spread across a number of relatively small facilities rather than just one or two large facilities such as occurs in the pulp industry.

The capacity of these plants to pay for biomass feed is closely linked to the production cost of the biofuel (which should reduce over time with industry maturity) and the comparable price for crude oil (which is currently at a long term minimum but is expected to increase over coming years). Such an industry can potentially provide local value-adding for processing, plantation and native forest residues. Any use of the latter feedstock will benefit from community engagement to discuss the social, environmental and economic benefits of a local renewable fuel industry and the sustainability protocols for use of such residues.

Tasmanian biomass residues are available at a range of prices. Any initial commercial development would be expected to utilise the feedstock at the lowest available price. The ability of the industry to grow over time will depend on its capacity to progressively utilise residues from a wider range of sources. Where there are existing end markets, any drop-in hydrocarbon biofuel development would need to demonstrate a greater capacity to pay for biomass.

Uncertainty over the cost of feedstock supply and end product demand represent key barriers to the establishment of a biofuel project. Project proponents would seek multi-year feedstock supply agreements as well as a multi-year sale agreements. For example Red Rock's biofuel development in the US has offtake agreements with the US Air Force and other commercial airlines to provide part of the security necessary for the development of its new facility.

Table 7-8 summarises some of the key considerations for further development of the hydrocarbon biofuels potential.

Table 7-8: Summary of Key Considerations for the Development of Drop in Hydrocarbon Biofuels in Tasmania

Criteria	Key Considerations
Key Success Factors	Drop-in hydrocarbons should integrate seamlessly with the existing supply chain infrastructure and avoid issues of scale and acceptance that are found with ethanol blends Significant volume of uncommitted residues available
Key Challenges	Multiple technologies are being developed to produce biofuels but there is no clear superior technology Demonstrating certainty for feedstock supply and product offtake conditions to attract experienced international biofuel companies Long timeframe expected until advanced biofuel commercialization becomes widespread
Barriers to Entry	Proving cost competitiveness with oil-based transport fuels Opposition to the use of native forest residues for energy Capital costs – substantial investment potentially up to several billion dollars required to establish a greenfields opportunity Engagement with the existing fuel supply chain in Tasmania
Collaborators	International proponents offering licensed technology Residue producers with limited access to markets
Competitors	Oil companies Existing residue users Alternative technologies such as electric vehicles which can also displace fossil fuels
Policy Considerations	Extension of the federal subsidies that already apply to biodiesel and ethanol in Australia to include hydrocarbon biofuels Attract investment to Tasmania (as opposed to other states and countries) via a clear commitment of support for the industry
Potential Timeframes for Further Development	See analysis below

Facilitating Future Development

International developers of commercial biofuel technologies range from dedicated companies through to specialist units within multi-billion dollar global corporations. They have the capacity to develop projects alone or in collaboration with others. If these proponents consider that establishing biofuel plants in Tasmania is commercially attractive, and that Tasmania is a good place for business, they can be expected to take the lead role in determining project feasibility, fund-raising, construction and operation of biofuel plants in the state.

The Australian government has a variety of initiatives to support commercial production of biofuels. These include:

- The Australian Renewable Energy Agency, which can co-fund essential pre-commercial work such as supply chain development and detailed feasibility studies for commercial plants;
- The Clean Energy Finance Corporation, which can take the lead in organising debt for commercial renewable energy projects;
- The R&D Tax Incentive; and
- Partial exemption from excise on eligible biofuels (currently in place for ethanol and biodiesel), with potential for extension to hydrocarbon biofuels.

It is to be expected that industry and the Australian government will take responsibility for the majority of the investment needed to develop and implement commercial biofuel plants. All biofuel project developments to date have required a considerable degree of government support. This is likely to continue for the foreseeable future, but is no different to the steps taken to promote the development of the wind and solar energy sectors. There is also an important role for state government - focused on facilitation rather than direct investment.

Global interest in hydrocarbon biofuels could increase rapidly as initial commercial plants enter operation, and any state seeking to develop its own biofuels industry will need to attract potential developers. While there are a number of commercial developers, their ability to initiate new projects is still limited and they will gravitate toward regions that clearly demonstrate the combination of feedstock availability and security, government support for biofuels and a low-risk environment for investment. For example, Queensland has recently prepared a biorefinery report, engaged with interested customers (US Department of Defence) and developed a mandate strategy to encourage increased local biofuel production.

Factors working in Tasmania's favour for the development of drop-in hydrocarbon biofuels include:

- A significant volume of uncommitted residue fibre;
- A favourable investment climate; and
- Government enthusiasm for development of a new industry based on woody residue utilisation and a willingness to reduce reliance on imported fuels.

With a suitable hydrocarbon biofuel strategy, the Tasmanian government might catalyse significant investment by industry and support by the federal government. A biofuels industry will require the participation of a number of stakeholder groups and a benefit of state government involvement is its ability to facilitate such participation. Relevant groups include:

- Feedstock providers;
- Partners, engineers, fabricators for the plants;
- Funding organisations to finance the plans;
- Distribution and marketing of products;
- Community consultation and support for the industry and its products; and
- State and federal government support for industry infrastructure, product certification, incentives for CO_2 mitigation, and project permits.

The steps to reach a first commercial plant include:

- Consideration of government's policy position on hydrocarbon biofuels;
- Community and industry engagement;
- Feasibility work for commercial projects (funded by industry, potentially with federal government grant support); and
- Agreements, permits and funds for a commercial plant(s).

If the state government facilitates such activities it is feasible that construction of a first commercial biofuel plant could commence in 4 to 5 years from initiation.

8. WOOD PELLETS

8.1 Option Summary

Renewable energy policies have driven the development of global wood pellet consumption patterns. These policies mostly relate to heat and electricity generation through the use of wood pellets as part of a carbon emissions reduction framework. With many policies being nationally based, the pellet trade has responded according to both the respective national policy targets and the potential for domestic pellet supply. While the policy modalities can vary by jurisdiction, infrastructure arrangements and location of pellet consumers all influence the demand and form of the global pellet trade.

The 2014 global trade of wood pellets was estimated to be ~28 million tonnes, with 70% of this trade occurring in Europe. The bulk of the pellet supply to date has been from European states. With continued expected growth in European demand, pellet sourcing is likely to be increasingly met from supplies outside of Europe given the reducing potential for securing additional domestic supply. With a well-established supply chain from the US and Canada into European markets, further increases in demand are likely to see an expansion in the North Atlantic pellet trade.

Within the Asia Pacific region, policy developments have resulted in a marked increase in the import of pellets into Japan and South Korea. Current policy settings are expected to result in further growth in the pellet trade through to 2020 for both countries but South Korea in particular.

Japan and South Korea represent the most prospective markets for Australian sourced pellets, given proximity in terms of transport distance, delivered cost and traditional trading party status with these two countries in wood products.

Current global trade is largely around white pellets, where wood is pulverised and compacted suited for transportation. While black pellets (torrefied) offers significant benefits in terms of the transportation efficiencies due to pellet energy concentration, little commercial development of black pellet manufacturing has occurred to date.

The Japanese supply to date has primarily arisen from Canadian exporters, while South Korea has sourced predominantly from Asia Pacific and particularly Vietnam and China. Given white pellet feedstock can range from a variety of tree species along with non-woody supplies such as palm oil bunches and rice residues, increasing import demand from Japan and Korea is likely to be met from a range of existing and emerging suppliers throughout the Asia Pacific region.

International pellet pricing to date has been relatively volatile, partly reflecting the emerging development of market norms and diversity of potential suppliers. A key price indicator has been the delivered price into Korean and Japanese ports (as in CIF), with prices generally varying in a band from USD150/tonne through to USD250/tonne, although the South Korea pellet price is currently below this range.

Given the relatively low capital costs, and flexibility in feedstocks that meet the market requirements, a wide range of new pellet plant developments are under consideration through the Asia Pacific region.

Tasmanian produced pellets have the potential to be a supplier to these north Asian markets. With pellet plants ranging from 75,000-150,000m^3/year, Tasmania has a number of locations with adequate supply to support a pellet mill development.

Current cost estimates for constructing and operating a pellet plant indicates a Tasmanian exporter would be able to compete domestically for fibre (i.e. log purchasing) when CIF prices approach and exceed USD200/tonne CIF to Japan or Korea, given an exchange rates of around ~AUD0.75:USD. However as prices move towards and below USD150/tonne, the supply chain would not be able to compete to purchase logs, with little profit margin available.

Pellet manufacturing represents product development outside traditional wood products markets such as pulp and paper or timber or panels manufacturing. This diversification can support a business case, particularly where industry participants are able to access both processing residues and logs. A further key component for a viable business case would be establishing a clear route to market, and amelioration of price and volume risk to an acceptable level.

8.2 Wood Pellet Markets

Wood pellets are primarily utilised for combustion to produce heat and electricity. Demand for wood pellets is driven by renewable energy policies with wood pellets classified as a renewable fuel having zero carbon emissions. Pellets come in three main forms:

- **White pellets** –produced from pulverised wood fibre which is pressed through a perforated matrix or die to produce a uniform dimension and density pellet;
- **Black pellets** –produced either through a steam explosion process (thermal treatment at 180-220^{0}C under pressure followed by rapid pressure release) or a torrefaction process which involves the thermochemical treatment of biomass without oxygen at 200-300°C to remove additional moisture and increase energy density; and
- **Non-wood pellets** – are pellets made from a range of non-wood biomass sources such as rice husks, straw or Palm Kernel Shell (PKS).

Virtually all wood pellets traded to date are white pellets. Black pellets are an emerging product that are currently at a development stage. Non-wood pellets are relatively new as agricultural and horticultural producers look to generate new markets for what has traditionally been considered a waste product.

Market Demand for Wood Pellets

Global consumption of wood pellets has grown steadily over the past 15 years. As of 2014 the annual global market size was estimated to be around 28.4 million tonnes. At 20 million tonnes, Europe is the world's single largest biomass pellet consuming region. North Asia, is the world's second largest consuming region with approximately 4.1 milllion tonnes followed by North America. Much of North Asia's demand is centred on China[67], nearly all of which is met through local supply.

Two other North Asian markets, Japan and Korea, are important, not only in terms of size and growth potential but because both are the main markets for internationally traded biomass and biomass pellets. Pellet demand in Korea was estimated to be 1.7 million tonnes in 2014, 95% of which was imported. Pellet consumption in Japan was around 190,000 tonnes in 2014, roughly half of which was supplied by imports. In addition, both countries import other biomass such as PKS and wood chip (Japan).

Europe

For Europe the main driver for increased pellet consumption is the climate and energy package of the EU. This binding EU legislation was enacted in 2009 and sets three key objectives to be met by 2020:

- A 20% reduction in greenhouse gas emissions from 1990 levels;
- Raising the share of EU energy consumption from renewables to 20%; and
- A 20% improvement in the EU's energy efficiency.

Renewables made up 14.1% of EU energy in 2012. Predictions for increased wood pellet consumption to 2020 are based on the 20% renewables legislation. Beyond 2020, the EU has agreed to an energy policy framework for 2030 that includes raising renewable energy to 27% of the EU's energy consumption.

[67] There is no official data on pellet production and trade in China. There are various market reports available but indications from local sources is that there is little information available and there are reliability issues with existing data. Nonetheless there are strong indications that China's annual domestic consumption of wood and non-wood biomass pellets is around two million tonnes.

The European pellet market was initially fully met by domestic production. However, as demand grew, imports were needed. EU pellet imports are primarily sourced from eastern Canada (2,500-3,500 nautical miles) and the south-eastern United States (4,000-5,000 nautical miles). These regions large, established forest industries and increased available residue supply. They now have many large, well-established pellet plants and transport infrastructure capable of moving millions of tonnes of pellets each year.

In contrast the distance from Tasmania to European ports (some 11,200 nautical miles from Bell Bay to Rotterdam) represents a significant competitive disadvantage and means it is unlikely Tasmania could competitively participate in EU markets.

Korea

Korea's Renewable Portfolio Standard (RPS) is the key policy driving biomass pellet demand to date. The RPS came into effect in 2012 and imposes an obligation on power companies with more than 500 MW of generation capacity to ensure that a certain percentage of their energy is generated using new and renewable energy (NRE) technologies. Thus the six major electricity generation companies (GenCos) owned by the Korea Electric Power Company and seven independent power producers are currently obligated to produce 3% of their projected power generation using NRE. Under the current policy this obligation increases progressively to 10% of power generation using NRE technology by 2024. Further amendments to the RPS are in discussion which may see the obligation period extended to 2027 but without change to the overall obligation target.

Companies that fail to comply with the regulations have to pay a penalty, which is 150% of the average Renewable Energy Certificate (REC) price for the year. The RECs thus have a market value and the intention is that the value that RECs generate would support the financial viability of investing in NRE technologies. To further support some of the NRE technologies, the Korean government has set multipliers (ranging between 0.25 and 2) for eligible NRE technologies. For example, generating electricity using a dedicated biomass power production attracts a multiplier of 1.5 whereas the co-firing of biomass attracts a multiplier of 1.0.

While the RPS does not place any preferences or limitations on the origin or type of biomass companies use in meeting their obligations, various legislative and regulatory requirements have placed some restrictions on what type of biomass is eligible. For example, the importation of non-wood (e.g. pellets based on oil palm empty fruit bunches (EFB)) was not allowed as a result of the material having a "waste" classification (the importation of which is restricted in Korea). However, from July 2014 the legislation was amended to allow to allow EFB pellets to be supplied to the market. Other restrictions such as minimum calorific values, co-firing limits and limitations on the moisture content of imported biomass, remain. Recently the Korean government has also included sustainability certification as an additional requirement for imported biomass pellets, though it is not clear whether this is mandatory.

In addition to the RPS Korea has adopted an emission trading scheme (ETS) which came into effect in January 2015. The ETS is a 'cap and trade' programme with the cap set at 573 million tonnes carbon dioxide equivalent for 2015. The cap is expected to be reduced over time in line with the Governments intentions to reduce greenhouse gas emissions. Targets have been set for 2020 and 2030. The 2030 target is 37% below business as usual and has been described as mandatory covering the steel, cement and petro-chemical industries, refineries, power generators, buildings, waste sectors and the aviation industry. In total 525 business entities including domestic airlines are liable. There is also provision for voluntary opt–in to the scheme.

The ETS is expected to further support NRE generation by encouraging fossil fuel energy generation to switch to renewables such as biomass. In this regard the ETS system also has direct applicability to the GenCo's seeking to reduce carbon emissions at coal plants through co-firing. Since mandated companies include petrochemical, cement and steel producers, there will also be focus on manufacturing process related use of fossil fuels switching to biomass.

Japan

Japan's original RPS started in 2003 with the aim of encouraging NRE development. It was dominated by the regional utilities and the focus was on power generation. By 2010 the RPS being criticised for the slowness of NRE growth.

Following the Fukushima earthquake in 2011 Japan's whole energy policy underwent a re-examination and a Feed in Tariff (FIT) system was introduced as the key mechanism to increase the share of the electricity produced by NRE technologies. While the RPS was aimed at Japan's major utilities and encouraging NRE development there, the FIT was expanded to include private entities.

Japan's FIT covers several different technologies (solar, wind, hydro, geothermal and biomass). The tariff levels for each of these renewable energy technologies were first set in June 2012. FIT's are subject to annual review with the government adjusting rates to encourage (or discourage) investment in the various technologies. The initiation of the FIT saw substantial investment in solar power which had preferential tariffs at the time. Since then however the government has steadily reduced the FIT for solar as a means of discouraging further investment in that technology. In contrast, uptake of the FIT for biomass electricity generation has been relatively slow and as such the government has left tariffs for biomass and their categories unchanged.

Table 8-1 shows that under the FIT the government sets five tariff levels, each applying to biomass of a different type, form and origin. The application of a different tariff for different categories of biomass is deliberate. The category "unused wood combustion" attracts a higher tariff than other wood sourced categories as a result of the government's desire to support rural economies and the domestic forest sector as well as utilise domestic forest resources, especially thinnings from existing plantations. As a consequence most of the biomass power generation applications under the FIT have been focused on the highest biomass category, thereby placing the focus on supply from domestic biomass sources.

Table 8-1: Current Japanese Feed-in Tariffs by Biomass Category

Biomass	Methane Fermentation Gasification	Unused Wood Combustion (1)	General Wood Combustion (2)	Waste Combustion(3) (excl wood)	Recycled Wood Combustion (4)
Price (JPY/kWh)	40.95	33.6	25.2	17.85	13.65
Period (yrs)	All categories, 20				

Notes:
1) Thinnings and mature stand harvest certified as "unused"
2) Lumber mill off cuts, imported wood, PKS, rice husk, rice straw
3) Green waste, sewage sludge, food waste, refuse derived fuel (RDF), refuse paper and plastic fuel (RPF), black liquor
4) Construction waste wood

In addition to the preferential tariff scale the Japanese government also requires that imported biomass meet sustainability criteria, although the type of certification required is not currently defined.

Other recent developments with regard to policy in Japan are sending mixed signals on the prospects for future biomass demand growth. Policy announcements on tackling greenhouse gas emissions are to be announced in late 2015. These are expected to provide considerable impetus to biomass demand from coal plants seeking co-firing options. It is quite possible that Japan's state owned utilities may be mandated to reduce emissions. This would stimulate biomass demand.

Conversely, the government is also reviewing the subsidy structure for private companies retailing power to the market. Companies that have been planning additional power plant capacity to take advantage of the FIT and, more importantly the subsidy are now reconsidering, citing that proposed government changes will create an untenable level of risk to profitability as the subsidy would be based on a market price rather than a fixed price. This increase in revenue uncertainty could result in a sharp decline in actual biomass demand growth should these planned projects not proceed.

Australia

Given the form of Australian heating and power generation, at both an industrial and residential scale, and the related infrastructure along with the costs and reliability of these alternatives, domestic pellet demand represents a minor part of Australia's energy consumption.

Wood pellet plants occur in various locations around Australia. Typically the producers are oriented towards residential heating or small scale commercial/industrial consumers. In addition the pellets are marketed for other uses such as animal bedding given the potential absorption rates of the pellet.

Various companies are seeking to develop industrial end markets including power generators where they can align pellets to being co-fired with other feedstocks (i.e. bagasse) or traditional sources such as coal. These developments seek to benefit from the potential to store pellets in contrast to the seasonal supply of other renewable energy fibres.

While many of the wood pellet manufacturers are small scale, operators seek to sell product along the entire eastern seaboard to a range of end markets often differentiating the qualities of their feedstock (i.e. plantation vs native forest, hardwood vs softwood). Delivery is typically completed in 15-25kg bags via truck transport, rather than in bulk.

Tasmania

Tasmania is a major user of wood for residential heating but this is primarily in the form of firewood. The firewood industry is relatively open in Tasmania with the industry dominated by small business operators, such as wood-yards and individuals, who are involved in the collection and supply of firewood to customers. Alternatively, a significant portion of firewood is collected by the householder. Firewood is typically sourced from commercial forestry operations (post the completion of harvesting operations) and private land[32].

No detailed statistics are available but Rothe (2013)[39] estimates, based on a variety of sources that annual firewood consumption in Tasmania is between 290,000 and 350,000 air dry tonnes/year. Around 40%-50% of firewood is collected directly by the consumer with the remainder bought mostly from small suppliers.

Like other Australian states there is currently little demand for wood pellets for heating in Tasmania. Local pellet developments are occurring for a range of end uses, but only at a small scale to date.

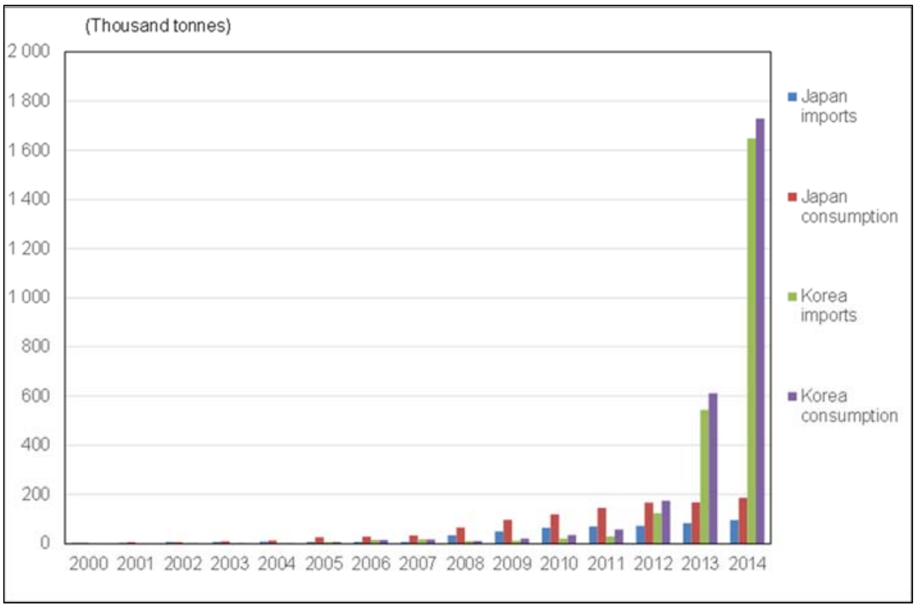
Japan and South Korea: Market Structure and Regional Supply

The use of biomass pellets for heat and power in Japan and South Korea has evolved over time. Within Japan the first pellet mills were installed as early as 1982 and after a brief period of activity (production peaking at around 28,000 tonnes in 1984) domestic pellet output declined as did the number of mills in operation. By the year 2000 only three mills were still operation and production was minimal.

Pellet production in South Korea is much more recent with the earliest mills installed around 2008. In both countries domestic pellet production is dominated by a large number of very small facilities focused on producing pellets for commercial and residential heating.

In the last decade biomass pellet consumption in both countries has increased, driven mainly by the policies focused on power generation from renewable sources (Figure 8-1). Biomass pellet consumption for power generation is now the dominant use of pellets in South Korea and Japan.

Figure 8-1: Biomass Pellet Trade and Consumption in Japan and Korea



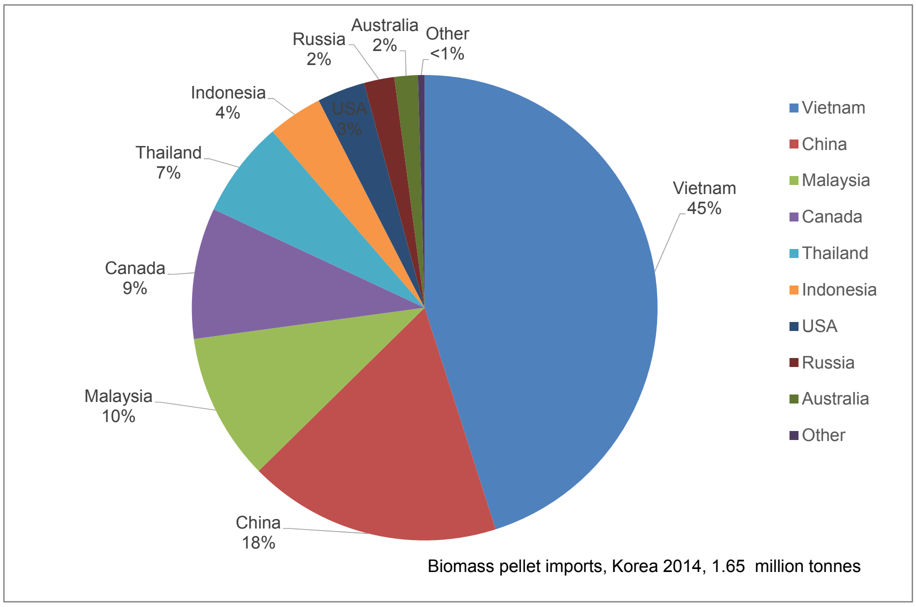
Source: Global Trade Atlas

Implemented in 2012, the impact of the RPS on biomass pellet demand in Korea is highly visible. Demand for biomass pellets in Korea has been met mostly through imports. Within Japan large volume imports of wood pellets commenced around 2008 and rose through to 2012. Estimates for 2015 however point to an expected near doubling of the 2014 import volume as biomass power plants constructed under the FIT begin operation.

Korea's policies are relatively supportive of the use of imported biomass in the form of wood, and more recently non-wood pellets. Other forms of biomass such as PKS are also being imported but only in very small volumes. Restrictions on biomass moisture content currently effectively exclude the use of wood chip imports for power generation in Korea.

Korea imports biomass pellets from a number of countries (Figure 8-2). Supply origin has been highly variable over the last three years reflecting the nature of the supply tendering and trade process in Korea. During 2014 China entered the market and is currently the second largest supplier of wood pellets to Korea. Vietnam is currently the major supplier contributing about 45% of the supply to Korea in 2014. Much of the pellet supply is wood based, made from hardwood sawmill and furniture manufacturing residues including rubberwood. Supply from Canada is softwood pellets. Approximately 7% of imported pellets in 2014 were non-wood, predominantly EFB originating from Malaysia.

Figure 8-2: Biomass Pellet Imports to Korea in 2014



Source: GTI trade data and Indufor. Analysis and interpretation by Indufor

Japan's greater focus on the utilisation of domestic sources of biomass, as well as greater acceptance of different forms of imported biomass for power generation have been important factors in the relatively muted growth of biomass pellet imports, even with the RPS and FIT policies. It is understood that until 2012 one utility in Japan was importing up to 300,000 BDMT of wood chip annually for power generation. Volumes have since reduced in the wake of the Fukushima disaster, but Japan still imports wood chip for energy generation. PKS imports have also been increasing rapidly in the last three years with an estimated 240,000 tonnes of PKS imported in 2014, compared with 124,000 tonnes a year earlier.

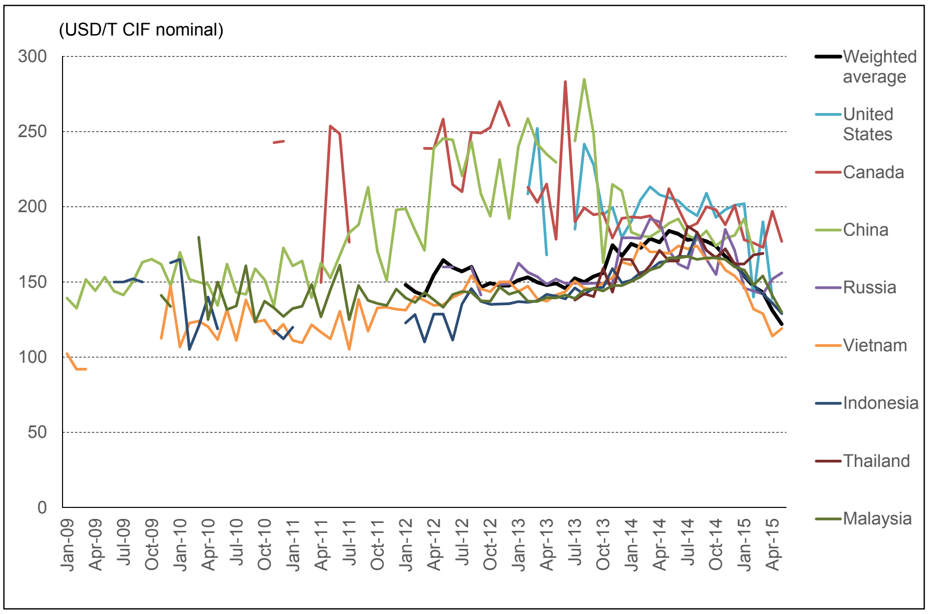
Unlike Korea, the supplier profile to Japan has remained very stable with pellet supply from Canada accounting for 90-95% of total pellet imports, all of which are made from softwood processing residues. Small volumes of pellets from Thailand and Vietnam have also been supplied, presumably on trial basis as have pellets from Indonesia and Malaysia. During the first six months of 2015, supply from China has become a feature of the market, and the expectation is that the supply of biomass pellets from China and Vietnam should increase in 2015.

Wood Pellet Price Trends

Prices for internationally traded biomass pellets reflect buyer behaviour in each respective country. Korean GenCo's to date have offered short term contracts lasting between 1-3 months, usually on a delivered duty paid basis and at relatively modest prices. Contract stipulations have also been strict in terms of quality and the mode of delivery.

Discussions with pellet traders have reflected a deep sense of uncertainty and concern at ill-discipline in the trade process since the market began developing in earnest during 2012. Key issues have included high variability in pellet quality (with shipments from Malaysia and Vietnam being rejected due to quality issues) and where even a contract is no guarantee that the trader won't cancel shipments without notice, or seek to renegotiate prices. Many suppliers point to extremely short term tenders as being a major issue creating uncertainty in the market, which has not been conducive of price stability. CIF prices in Korea have therefore been distinctively more volatile than in Japan (Figure 8-3).

Figure 8-3: Imported Pellet Price Trends - Korea



Source: Global Trade Atlas

The considerable decline in Korean CIF prices since August 2014 has largely been a result of pellet oversupply situation created amidst an environment where inventories were being built by traders in anticipation of securing contracts. The subsequent oversupply realization has since led to a price crash (led by Vietnam followed by Indonesian and Malaysian producers) to levels well below what would be considered by most producers as sustainable for long term supply.

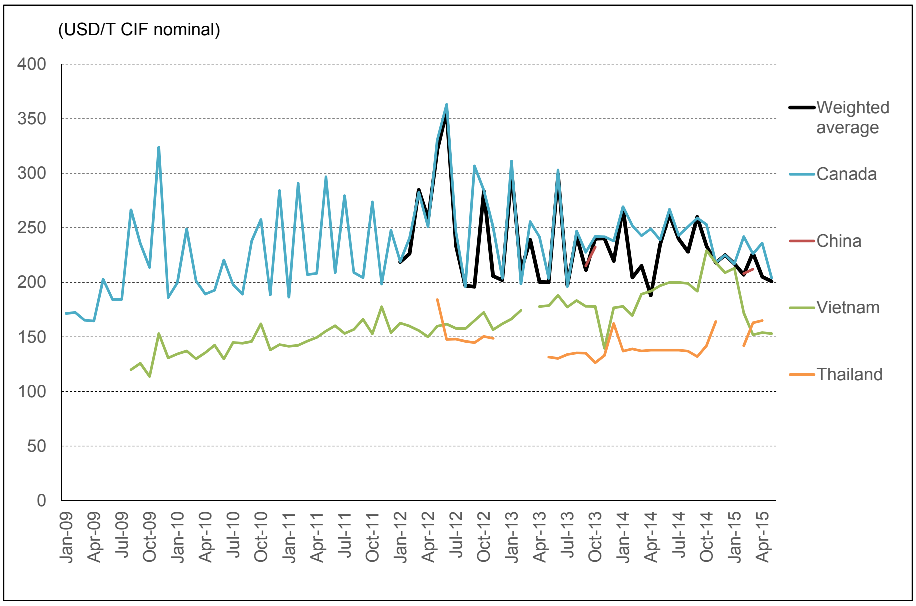
Canadian suppliers however have by and large maintained their prices, albeit at the cost of reduced volume. Other suppliers such as China and Thailand have simply opted out of the market for the time being. Discussions with Thai producers indicate that from March to May 2015, many small mills had simply stopped operating as the market price was not sustainable. Latest market references point to a stabilization and rebound in the Korean market as supply, demand and inventories return to more reasonable levels.

In contrast CIF prices in Japan have remained steady at around USD200/t CIF (Figure 8-4). Most suppliers to the Japanese market (primarily the Canadian's) have maintained price position even when the Korean market prices dropped. Chinese and Thai suppliers have maintained prices, and only in the last few months have Vietnamese prices declined sharply[68].

Japanese buying philosophy differs in many ways to the Korean approach. Trading houses are more interested in securing supply that is sustainable in the long term and provides the right quality for their needs. They are also interested in ensuring that quality does not vary so that there is greater certainty over how the pellets will perform in a boiler. Tenders and contracts therefore tend to be long term (5-10 year contracts for example) and there is greater appreciation for the importance of maintaining a supplier to ensure these conditions are met.

[68] The supply from Vietnam to Japan is very small and is probably being purchased for trial purposes in Japan. As a consequence it is unlikely that any contract is in place and Japanese buyers are probably purchasing at spot prices, benefiting from uncertainty in the Korean market

Figure 8-4: Imported Pellet Price Trends - Japan



Source: Global Trade Atlas

The FIT also allows Japanese buyers a greater certainty regarding price compared with their Korean counterparts. The combination of these factors have translated into prices that have generally been higher than Korea even for a similar product. However, it remains to be seen if this stability will continue in light of unfavourable exchange rate movements and increased competition for biomass.

Outlook for Biomass Pellet Demand in North Asia

Predicting how biomass demand in Japan and Korea may develop over the coming years is highly dependent on policy decisions in both countries.

Japanese policies toward carbon emission abatement and GHG reduction could have a significant impact on biomass demand within the country. To date the Japanese government has vacillated over the question of emission reduction, even though relatively comprehensive plans were in place before the Fukushima disaster. Consequently, there has been almost no move by any Japanese power entity to consume biomass in an effort to reduce emissions. Predictions of biomass consumption based on such a scenario have therefore failed to materialize. Added complications include the near absent policy in Japan toward district heating and the support of commercial and residential heating projects. Heat is one of the most efficient uses of biomass for energy generation but as of May 2015 there has been little official encouragement to use biomass for heating. GHG reduction policies may change this, which may result in increased pellet demand.

Only the FIT presently provides some basis for predicting biomass demand in Japan, and even here, frequent changes in policy are impacting on biomass demand making forecasting volume consumption unpredictable.

In Korea the RPS provides some capacity to predict biomass demand, based on the obligation, government announced plans and the GenCo's stated intentions in renewable energy generation. Less predictable is the potential impact the ETS will have on biomass consumption, especially given it only started in 2015 and the value of units is still being established.

Table 8-2 provides a forecast of future biomass demand and the international biomass pellet trade to Japan and Korea. In making predictions on traded biomass pellets it is important to account for demand that will be satisfied through domestic biomass supply, and that not all biomass for power generation will be in wood pellet form. In particular the Japanese market for internationally traded biomass will include wood chips as well as pellets. The demand projections provided in Table 8-2 do not account for the possibility of black pellets which may lead to a greater level of substitution for coal. Black pellets are not a feature of either market at present.

Table 8-2: Outlook for Biomass Consumption & International Biomass Pellet Trade

	2015	2020
Demand for biomass for energy generation (million tonnes pellet equivalent)		
Japan	3.9	5 - 10
Korea	2.5	6 - 9
Internationally traded biomass pellets (million tonnes pellet equivalent)		
Japan	0.3	1 - 3
Korea	1.9	5 -7

The expectation is that by 2020 biomass demand in Japan and Korea combined is likely to be around 13 million tonnes on a pellet equivalent basis. For Japan demand is expected to be around six million tonnes. As much as three million tonnes of this could be satisfied through domestic biomass supply, the balance being met from imported biomass in a variety of forms of which biomass pellets are expected to constitute between one and three million tonnes. Virtually all of the internationally traded biomass pellets will most likely be in the form of wood pellets from residue sources or plantation wood. Natural forest fibre is unlikely to be a component of the demand for wood pellets.

For Korea expected biomass demand in 2020 is likely to be higher (seven million tonnes pellet equivalent) than in Japan. Unlike Japan, the expectation is that most of this will be satisfied by international biomass pellet trade. Most of this will be wood pellets though the expectation is that up to 10% of traded volumes could be non-wood (predominantly EFB and rice husk) pellets.

Sawmill residues will continue to be an important element in the biomass fibre furnish, including processing residues that have originated from native tropical hardwood. Increasingly plantation hardwood residues and pulp logs are expected to make up a greater component of the biomass pellet supply.

In total, the regional trade in biomass pellets is anticipated to have the potential to reach around six to 10 million tonnes by 2020. This is far lower than the potential volume biomass available from within the Asia Pacific region, which would allow the purchaser to be more selective about where the biomass is sourced from.

There are considerable volumes of biomass available within the Asia Pacific region. The sustainable supply potential within the Asia-Pacific region suitable for pellet production is likely to be between 45 to 50 million tonnes/year (though this will vary depending on how much biomass is really available from pulpwood sources). As regional supply availability expands, this could increase to between 55 and 60 million tonnes/year over the coming 15 years.

There are also substantial volumes of non-wood residues available in the region. For example, the oil palm industry waste available in Malaysia alone is estimated at more than 80 million dry tonnes per year. It is estimated that 25 million dry tonnes/ year of fibre could be aggregated at Malaysian ports for an average cost of less than AUD90/ dry tonne. South Korea has recently allowed pellets from PSK into the country and Malaysian companies are already making PSK pellets at small scale.

Agricultural residues are not necessarily a direct substitute for wood in pellet manufacture, as they can contain significantly higher levels of inert material that creates ash in the power plant. Coal-burning power plants are designed to manage the quantities of ash expected from coal. If a significant amount of pellets are substituted for coal and those pellets have relatively high ash content, the ash handling system of the power plant may become overloaded. This effectively limits pellet firing levels and means low ash pellets (such as those made from clean stem wood) may be more acceptable and carry a price premium over high ash pellets made from agricultural residues.

8.3 Technology and Proponents for Production of Wood Pellets

White Pellets

White pellets are generally produced from sawdust, shavings, chips or bark that are first dried then ground to small particles. The particles are pressed through a perforated matrix or die. Friction from the pressing process heats and softens the lignin in the biomass making it more pliable. During the subsequent cooling, the lignin stiffens and binds the material together.

The pellet making technologies currently employed vary considerably across the region. Most pellet mills currently operating in China, Thailand, Vietnam and Taiwan are Chinese or Taiwanese in origin. Korean and Japanese plants are generally exclusively based on locally made equipment. Indonesian mills are primarily a mixture of Chinese, Korean and imported second hand lines employing European equipment. Malaysian mills are predominantly Chinese made, though often with substantial modification as it was discovered that turnkey Chinese equipment was unable to produce pellets of the required quality and maintenance costs were very high. Australian, New Zealand and Canadian mills tend to be based on European or North American equipment.

Regional trends in the pellet industry has show a shift from small scale pellet mills toward larger (75,000-450,000 t/year) mills, based more on European technology (either new or second hand). In Vietnam for example the current norm is for pellets to be made from sawmill and furniture factory residues with hundreds of small plants producing 1 to 4 t/hour. There is now a shift toward building much larger scale pellet mills based on processing plantation resources. The 120,000 t/year Cellmark pellet mill, currently undergoing trials in Sarawak Malaysia demonstrates the regional shift toward larger scale production. Pellet production scale in Thailand is also increasing though the approach has tended to be to achieve scale through adding multiple very small units at the same site to achieve a larger overall capacity (Figure 8-5).

Figure 8-5: Thai Pellet Mill Under Construction[1]

1) Each pellet mill can produce three tonnes of pellets per hour.

There is already substantial biomass pellet production capacity within the Asia Pacific region. Much of this is very small scale (plant sizes less than 50,000 t/year, more typically 5,000 t/year or less) and focused on domestic demand (commercial and residential heating, cat litter and animal bedding being typical end uses). Nearly all Japanese and Korean pellet production is focused on domestic needs, as is much of the China, New Zealand, Taiwan, and Singaporean production. However pellet mills in Canada, Thailand Vietnam, Indonesia and Malaysia are primarily focused on providing industrial pellets for export markets (Table 8-3).

Table 8-3: Regional Industry Capacity to Supply North Asia 2015

Country	Mills in Operation	Estimated Capacity (tonnes/yr)	Biomass Type	Planned & Decided Mills	Estimated Additional Capacity (tonnes/yr)	Biomass Type
Japan[1]	109	~170 000	SW temperate HW thinnings WPR	1	25 000	SW temperate HW thinnings WPR
South Korea[2]	21	225 000	SW temperate HW thinnings WPR	1	>500 000	SW temperate HW thinnings WPR
Russian Far East	2	250 000	SW and temperate HW WPR	1-2	200 000	SW and temperate HW WPR
Canada (BC only)	12	1 985 000	SW processing and harvest residues	4	>100 000	SW processing and harvest residues
China[3]	27	1 407 000	Wood and non-wood feedstocks incl. rice straw rice husk energy cane wood waste and WPR	4	350 000	Wood and non-wood feedstocks incl. rice straw rice husk energy cane wood waste and WPR
Taiwan[4]	3	60 000	SW & HW WPR	0	0	
Vietnam[4]	12	1 085 000	Mainly tropical HW WPR and rubberwood	11	1 500 000	Mainly tropical HW WPR and rubberwood rice husk and short rotation woody crops
Thailand[4]	6	290 000	Mainly tropical HW WPR and rubberwood	6	200 000	Mainly tropical HW WPR and rubberwood
Indonesia[4]	10	275 000	Mainly tropical HW WPR plantation HW and palm residues	4	350 000	Mainly tropical HW WPR and dedicated short rotation woody crops
Malaysia[4]	16	555 000	Tropical HW WPR EFB and palm residues	3	265 000	HW WPR EFB and palm residues. Dedicated short rotation woody crops
Singapore[5]	1	55 000	Industrial and commercial wood waste	0	0	
New Zealand	7	70 000	SW WPR and harvest residues	0	0	
Other (Timor, PNG Ph/pns etc)[4]				At least 3	>250 000	Energy cane and tropical HW plantations
Total	**120**	**4 385 000**		**32**	**>3 390 000**	

Key: WPR – Wood Processing Residue, HW – Hardwood, SW – Softwood, EFB – Empty Fruit Bunches

Notes:

1) The actual capacity of Japanese pellet mills has not been reported, but is largely believed that individual mills are very small
2) While there are plans for a very large scale pellet mill based in Korea and focused on supplying pellets to the GenCo's there is some scepticism this project will ever be realised
3) Data is based on available information. There is no firm data available on the number, type, location and capacity of Chinese pellet mills. Data represented here almost certainly underestimates actual number and capacity. Similarly projections are likely to be much higher than what is reported herein
4) There is no official data in these countries on mill numbers and installed capacity available. We understand that in Thailand and Vietnam at least there are hundreds of very small scale pellet mills, operating on an as needs basis. The numbers represented here primarily captures larger scale commercial operations
5) There is one pellet mill in Singapore though is not clear if this is still in operation

Table 8-4 provides a summary of various Australian wood pellet proponents and the typical feedstock utilised for pellet production.

Table 8-4: Summary of Australian Wood Pellet Proponents

Company	Location	Scale (t/year)	Feedstock Source	End Markets
Altus Renewables	Tuan, QLD	>100 000	Softwood processing residues	12-month contract for 50-75 000 t of pellets to Samsung, South Korea
Plantation Energy	Albany, WA	250 000	Softwood pulplogs, harvest residues	Pre 2012 – Europe 2015 – planned export to Korea/Japan
Pellet Heaters Australia	Woodburn, NSW	~3 000	Softwood processing residues	Domestic heating, animal bedding, spill absorbent
East Coast Wood Shavings	Gatton, QLD	~3 000	Softwood processing residues	Animal bedding and litter
Scottsdale Hop Growers	Scottsdale, TAS	~3 000	Hop plant residues	Animal bedding and local heating
Pellet Fires Tasmania	Glenorchy, TAS	~1 200	Hardwood processing residues	Local heating

It shows that domestic production to date has primarily occurred at a small, localised scale. The Plantation Energy facility in Albany, WA was originally developed to export pellets to power companies in Europe, but ceased operations in early 2012, citing a lack of suitably priced feedstock and the strong Australian dollar impacting on competitiveness. All of the plants except the Plantation Energy facility were developed to utilise processing residues.

Black Pellets

To date virtually all pellets have been supplied as 'white' pellets. As pellet markets expand and the requirement to handle and store pellets becomes more demanding, there is increased interest in torrefied as well as steam exploded pellets (black pellets).

Torrefaction involves the thermochemical treatment of biomass at 200-300°C so its physical and chemical properties are closer to the properties of coal. The main objective is to use torrefied biomass as a fuel to replace large volumes of coal in existing power plants. Steam explosion is a different but related process in as much that wet biomass is heated to temperatures of 180-220°C under pressure for a period of time before the pressure is explosively released.

The incentive for black pellets as opposed to white pellets is based on increased targets for renewable energy and the blending limits for wood pellets in many existing coal-fired power stations. In most plants, pellets are mixed with coal and sent together through grinders. However, wood pellets have different properties than coal, and can only provide up to 5-10% of the total supply before they begin to gum up the grinders.

Presently 3% is the accepted norm for co-firing in Japan and Korea, though it is understood that a blend of up to 10% is acceptable. In order to increase the proportion of biomass feedstock, these coal plants would have to invest considerable capital to upgrade their equipment. A possible alternative is to use black pellets, which have properties much more similar to coal, and can be used in coal-fired power plants without blending limitations.

Table 8-5 provides a comparison of the physical properties of wood as it is progressively modified into pellet and then black pellet form (via torrefaction) relative to coal, which provides the existing end-use benchmark.

Key benefits associated with the use of black pellets include:

- Energy densification that makes the energy content of black pellets comparable to coal
- Considerably more hydrophobic than white pellets and therefore less sensitive to water
- A product that can be pulverized as easily as coal
- Allows for transport efficiencies, and
- Believed to behave similarly to coal during combustion and have more predictable burning properties.

Table 8-5: Comparison of Key Physical Properties

Variable	Wood	Wood Pellets	Torrefied Pellets	Coal
Moisture content (% wt)	30-45	7-10	1-5	10-15
Calorific value (MJ/kj)	9-12	15-16	20-24	23-28
Volatiles (% db)	70-75	70-75	55-65	15-30
Fixed carbon (% db)	20-25	20-25	28-35	50-55
Bulk density (kg/l)	0.2-0.25	0.55-0.75	0.75-0.85	0.8-0.85
Volumetric energy density (GJ/m^3)	2.0-3.0	7.5-10.4	15.0-18.7	18.4-23.8
Dust	Average	Limited	Limited	Limited
Hydroscopic property	Hydrophilic	Hydrophilic	Hydrophobic	Hydrophobic
Biological degradation	Yes	Yes	No	No
Milling requirements	Special	Special	Classic	Classic
Handling properties	Special	Special	Easy	Easy
Product consistency	Limited	High	High	High
Transport cost	High	Average	Low	Low

Source: KEMA (2010)

Conditions favouring the use of black pellets include:

- The need to transport biomass to the power station from a considerable distance. The higher calorific value of black pellets means they can be transported a greater distance per unit of energy output than white pellets;
- Lower capital expenditure for a power generator required to increase biomass throughput;
- The desire to use a large quantity of biomass (more than 10% of station capacity) with minimal loss of power station output; and
- The lack of existing white pellet infrastructure (storage and grinding) at the power station. The hydrophobic nature of black pellets mean they can be stored outdoors.

The overall benefit that can be attributed to these issues will be influenced by the unique circumstances of each co-firing project.

This technology is currently at a formative stage with a number pilot and demonstration-scale plants in operation in Europe and North America and is still peripheral in the European market. Some torrefaction technologies are capable of processing feedstock with small particles such as sawdust and other are capable of processing large particles. Few can function effectively using a range of particle sizes.

Commercial production of black pellets is extremely limited. Two companies Arbarflame (Norway) and Zhilka chemicals (USA) are seeking commercial scale black pellet production, but both currently operate at a relatively small scale. Zhilka have announced black pellet supply contracts have been secured with the Municipal Authority of Paris and is looking to expand its production capacity with the construction greenfield facilities in Arkansas (proposed site) and Alabama (near commissioning). The Arkansas facility is expected to cost in the vicinity of USD90 million, excluding land acquisition costs.

Arbarflame are currently in discussion with Sojitz in Japan where testing of black pellets has been underway. We understand both companies use steam explosion technology to produce black pellets. Companies such as Zhilka deliberately avoid the terminology “torrefaction” to describe its manufacturing process.

Further development of black pellet technology will require a long term commitment from power companies to allow black pellet providers to set up and manufacture at scale.

8.4 Social and Environmental Considerations

Environment

Bioenergy is accepted as a renewable energy source globally with most governments providing favourable policy settings to promote its increased use. Bioenergy is considered renewable because the carbon dioxide released during combustion is supposed to be matched by the carbon dioxide captured from the atmosphere via photosynthesis that drives plant growth. However, this assumption has become more contentious in recent years given the GHG emissions associated with the transport of biomass from its source to end markets.

Wood pellets can be made from a range of residues from biomass left on the ground following harvesting through to the sawdust and other residues produced from making finished timber products. Most wood pellet feedstock is sourced from processing residues. However in some countries residues are collected from harvesting sites.

Studies have shown that removal of all harvest residues from a site has the potential to create a negative impact on the productivity of the subsequent tree crop. In a forestry context this can be remedied by the application of corrective fertiliser. In Australia there is limited interest in the collection of these harvest residues. Key reasons for this are the handling difficulty associated with managing small, irregular shaped pieces of wood and the low bulk density of this material, which makes it inefficient to transport. From a pellet making perspective, these residues also contain a high concentration of soil, which is very damaging to pellet making machinery.

The utilisation of biomass for pellet production would most likely be complementary to existing forestry operations, where the forests would produce a range of products, of which pellets may be one of the products produced.

Combustion of pellets creates flue gas, which is made up of the gaseous products of combustion plus entrained particulate matter. Combustion plants are therefore built to comply with local EPA regulations, which set acceptable standards for release of these materials into the environment. Before release to the environment the flue gas is cleaned to capture particulate matter.

Nitrogen oxides (NO_x) are also produced and limits may be set for their discharge. NO_x reduction can be achieved by modifying the combustion process.

Any substitution of wood heaters by pellet heaters is expected to have a net positive impact on smoke, other particulate emissions, and greenhouse gases as pellets burn more efficiently than firewood.

Construction of a wood pellet mill would have limited environmental impact. A small pellet mill would most likely be constructed within or close to an existing mill. It would be enclosed to protect machinery from the elements and reduce noise levels. There are few emissions from the manufacturing process and production does not require any additional chemicals.

A large scale pellet mill would have a larger footprint that would require a biomass storage area. The pelletising machinery would also be larger and would require on site fuel storage. Storm water and traffic control measures would most likely be required for a large scale mill.

Social

Within Australia there is a negative perception around the use of native forest residues for energy production. While the regulations restricting its use for this purpose were recently removed, there is still a strong sentiment against the use of native forests for this purpose. This contrasts with societal acceptance of native forest feedstock in heating and power production common across many northern hemisphere jurisdictions.

The level of employment associated with a pellet mill would depend on the scale of the operation. Small plants will have a relatively low labour requirement, whereas large stand-alone facilities will require more substantial labour inputs.

Pellet production is a highly mechanized manufacturing process. Pellet manufacturing is well understood with manufacturers able to provide off the shelf solutions. If the pellets are exported, the supply chain and labour utilisation would be comparable to woodchip exports as similar bulk handling, loading and shipping supply chains would be utilised.

8.5 Prospects for Wood Pellet Production in Tasmania

Wood pellets represent a market opportunity for Tasmanian residues because:

- Wood pellets have the capacity to displace fossil fuels as a renewable feedstock. This substitution process requires policy and market support;
- Demand in key markets of Korea and Japan is expected to increase over the medium term through the expansion of GHG emission reduction policies;
- Domestic consumption could arise in response to pellet production, providing an alternative market to exports; and
- Tasmania has a demonstrated capacity via its history of woodchip exports, to be a long-term supplier of forest products to North Asian markets.

End Markets and Feedstock Availability

As noted in the Stage 1 report, there is potentially a small market for wood pellets in Tasmania, particularly where LPG or electrical heaters are currently used. Possible customers include:

- Individual homes for heating and hot water;
- Small industries, such as dairying operations, for hot water production; and
- Heating municipal facilities, such as halls, schools, hospitals, and swimming pools.

These users would consume relatively small volumes. For example home heating can require as little as one tonne of pellets/ year. As an example the wood pellet heating system recently installed at Beaufort Hospital in Victoria is expected to consume around 100-200 tonnes of pellets/ year.

Wood remains a significant player in the Tasmanian energy market accounting for 6% of the state's total energy supply[32]. Residential heating accounts for the bulk of the with 25% or approximately 54 000 households using wood as their dominant form of heating (ABS 2015). However this has declined from an estimated 37% of households using wood in 2005[32]. The percentage of households using wood heaters varies from below 20% in urban areas to about 60% in rural communities[39].

The approach to these markets is purely commercial and not associated with any government incentives. As noted in Section 5, changes to the RET are unlikely to result in any substantial increase in demand from potential industrial users. Based on current market prices, wood pellets would find it difficult to compete commercially against firewood gathered by individuals or against natural gas. Small scale pellet production in Tasmania is expected to come from the use of sawdust that is currently going to landfill or other processing residues, such as the operation developed by Pellet Fires Tasmania in Glenorchy.

Large scale industrial demand for pellets, relevant to Tasmania is likely to arise from Japanese and Korean GenCo's. Tasmanian forest and processing residues could potentially be converted to wood pellets and exported to these markets. Any wood pellet development in Tasmania would need to be competitive with other domestic and international suppliers.

Pellet plants can be established to operate at any scale, utilising a range of feedstocks. Existing pellet manufacturers in Australia are primarily sourcing sawmill residues or municipal consumer waste. An export oriented pellet mill would require a feedstock of at least 125,000 tonnes of residues/ year. This would be the minimum volume required to deliver multiple bulk shipments a year to end markets.

A pellitising facility operating at a smaller scale is possible, but it would need to be integrated with a woodchip export operation to supply partial shipments. Logistically this would be most efficient if the woodchips and pellets were delivered to the same port. Delivery to separate ports would increase cost and increase the risk of demurrage payments to the ship owner.

Table 8-6 shows the various residue types available in Tasmania that are suitable for pellet production. Processing residue volumes are sourced from an unpublished NCFFI report. The processing residue data is presented as a cubic metre equivalent. Given the low bulk volume of many processing residues, the weight of this material (in tonnes) would be far less than the figures presented.

In aggregate, both the softwood and hardwood processing sectors produce sufficient residues to develop a large-scale pellet mill. However, both have a high level of existing residue utilisation, primarily as woodchip exports or boiler fuel. To justify a change in end use, pellets must demonstrate a greater capacity to pay, or represent a lower opportunity cost than existing residue markets.

In addition, the volume of residues available from the hardwood processing sector is spread across the state. The dispersed nature of these sites represent a key challenge for establishing a pellet plant due to the double handling required to consolidate either the feedstock or the finished product.

There is a greater uncommitted volume available from forest residues with hardwood plantations and native forests in particular having significant volumes available in most regions.

Other Stemwood is not considered to be suitable for pellet production. It is understood soil contamination in the harvesting residues resulted in very high maintenance costs at Plantation Energy's pellet plant in Albany, Western Australia.

Table 8-6: Wood Pellet Feedstock Potential

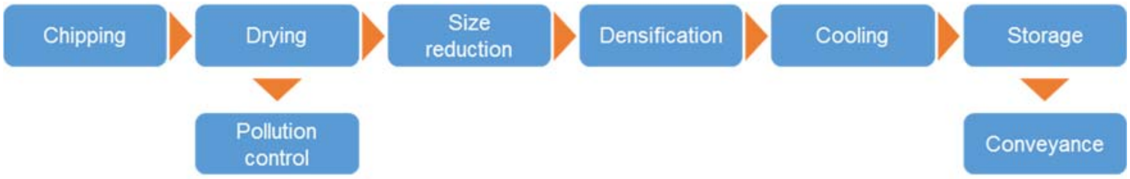
Residue Source	Residue Type	Estimated Availability ('000 units)	Currently Utilisation	Key Factors
Softwood processing	Sawdust, shavings, woodchips	150-350 m^3 eq.	Primarily woodchip exports & boiler fuel but also a range of other minor uses	Key producer has a large centralised location close to an export port Uniform wood properties Stable level of supply Softwood chip accounts for half the residue volume and is currently exported Extensive utilisation of existing residues
Hardwood processing	Sawdust, shavings, woodchips	80-120 m^3 eq.	Variety of end uses	Producers dispersed across the state and therefore costly to aggregate to achieve sufficient scale Variable wood properties (multiple species) Additional R&D may be required to determine most appropriate pelletising technology
Hardwood veneer	Woodchips offcuts	20-30 m^3 eq.	Boiler fuel and firewood	Volume too small for stand-alone plant Pellet returns would have to exceed opportunity cost for running the boiler
Plantation softwood	Log and woodchip	450-600 GMT	Log and woodchip exports	Huon/Murchison/Mersey have < 125,000 GMT necessary for a stand-alone plant based on softwood plantations. Would need to combine with other forest/ processing residue to achieve necessary scale
Plantation hardwood	Log and woodchip	3500-4000 GMT	Log and woodchip exports	All regions have sufficient volume for a stand-alone pellet facility of at least 125,000 GMT/year Chip mills also produce a range of out of specification material suited to pellet production
Native hardwood	Woodchip	1000-1300 GMT	300-500 woodchip export	All regions except Mersey have > 125,000 GMT/year required for stand-alone pellet plant based on NF residues. No static chipping capacity in Huon region Limited competition for this product may make this this product attractive for a buyer
Other Stemwood		Nil	Nil	Not attractive for pellet production due to issues with collection cost and soil contamination of feedstock resulting in excessive wear on pelletising dies

Source: NCFFI (unpubl), FT, PFT

Economic Considerations

Figure 8-6 shows the individual elements involved in the pelletizing process. Given that the process of making pellets has been around for at least 50 years the equipment required at each stage is fairly well defined with multiple suppliers.

Figure 8-6: Pellet Making Process



There are a large number of machinery and equipment manufacturers offering customised components as well as total turnkey mill options for the would-be buyer. Companies supplying pellet mills or equipment components include Andritz, Salmatec, Kahl, Prodesa, Dieffenbacher, CPM, Halla, and Liyang Yuda amongst a host of other US, Canadian, Asian and European solution providers. While each equipment supplier strives to differentiate themselves, the main differences in equipment supply revolves around the selection of dryer technology (belt versus drum drying) emission control technology, densification (ring dies versus flat dies) and pellet handling.

Pellet mills are moderately capital intensive with even relatively small mills requiring significant capital investment in machinery as well as site and civil engineering, buildings, storage and recovery facilities, conveyors and mobile plant.

As this analysis is focused on only broadly understanding the economic performance of a range of options, comparing available information on investment costs by mill capacity is a useful tool for at least providing an indication of expected investment cost. Table 8-7 summarises interpolated investment costs for a range of mill capacities.

Table 8-7: Indicative Captal Costs & Cost Ranges for Different White Pellet Mill Capacities[1]

Plant Capacity (000 t/year	Estimated Capital Cost (USD million)	Estimated Capital Cost Range (USD million)
10	3	2-5
50	14	10-17
100	27	24-30
125	35	31-38
150	40	38-45
200	52	48-56
250	64	61-67

Note:1) Interpolated capital costs include civil engineering, buildings, mill equipment, conveyance equipment, mobile plant, storage and loading, building costs and contingencies. Specifically excluded are any costs of financing or any independent power plant for electricity

At present there are no large-scale torrefaction plants in full commercial operation anywhere in the world, and little published data as to the costs expected for such plants. The cost of a torrefaction plant will be similar to that of a pellet plant but with the addition of a torrefaction unit. In the absence of any firm cost data it is suggested that for the manufacture of torrefied pellets the pellet plant cost be increased by 20% to allow for the additional equipment and related civil/structural/electrical work.

Since torrefaction (or steam explosion) units are modular and separate from white pellet production, they can be ‘dropped in’ to an existing white pellet mill operation providing the flexibility for producers to switch between black and white pellet production.

Mill operating costs can be broken down into three elements: variable costs (heat and electricity costs and raw material costs such as the cost of biomass), fixed costs (labour, materials and repair and maintenance) and capital costs. The key costs for any pellet mill is primarily the cost of the raw material for making pellets followed by energy costs (drying wood and powering the mill).

A Tasmanian pellet mill producing around 125,000 t/year of pellets will have an operating cost structure (excluding feedstock charges) between 40-60 AUD/ tonne pellet equivalent (tpe). The lower bound of the range assumes only wood processing residues are used. The upper bound assumes only pulp logs are used (Table 8-8).

Table 8-8: General Estimate of Mill Operating Costs for Tasmania (excl Feedstock)

Parameter	Operating Cost (USD/t pellet - 10% MC)	Operating Cost (AUD[3]/t pellet - 10% MC)
Variable costs (heat, electricity)[1]	20-25	27-33
Fixed costs (labour, materials, R&M)[2]	10-20	13-27
Total	**30-45**	**40-60**

Notes:
1) Wood is used in a boiler to dry wood chips so there is a drying cost. Electricity is assumed to be supplied from the grid at AUD11 cents per kWh.
2) Current labour rates have been assumed and staff numbers are capped at 16. Repair and maintenance costs are based on industry standards
3) Assumed exchange rate is (AUD0.75/USD)

These costs should be considered indicative and are influenced by exchange rate assumptions.

International shipping represents a substantial component of the cost to deliver pellets to North Asian markets. Shipping costs are a function of distance, sailing time and cargo volume. Larger ships can carry larger payloads, thereby reducing unit costs. Table 8-9 highlights the distance from various potential sources of supply to Tokyo Bay in Japan and Incheon in Korea.

Shipping costs have historically been volatile with prices rising and falling due to trends in bulk commodities such as iron ore and coal. Prices are currently weak with the recent downturn in the Chinese economy.

Table 8-9: Transport Distances to North Asian Markets[1]

Port (country)	Distance to Tokyo Bay, Japan (nautical miles)	Shipping Cost Japan (USD/tpe)	Distance to Incheon, Korea (nautical miles)	Shipping Cost Korea (USD/tpe)
Vanino (Russian Far East)	1 100	8	1 500	9
Danang (Vietnam)	2 100	12	1 670	11
Kuala Lumpur (Malaysia)	3 200	16	2 760	15
Brisbane (Australia)	3 901	19	4 410	20
Prince Rupert (Canada)	4 150	20	5 590	26
Tauranga (New Zealand)	4 800	23	5 380	25
Bell Bay (Tasmania)	4 900	23	5 310	24

Note 1) the calculation assumes a Handy class vessel with a 35,000 tonne cargo hold, TC rates of USD7,500/day and a bunker fuel rate of USD500/tonne. Assumptions are also made for diesel prices, steaming speed (loaded and unloaded) and fuel consumption rates

To estimate what a Tasmanian wood pellet producer could potentially pay for residues a pellet supply model was developed to derive a mill door price for feedstock.

Key model assumptions in addition to those noted above include:

- A base pellet price of USD150/t CIF with supply assumed to be exported to Korea. This reflects a trend price for this market;

- Depreciation based on a capital investment cost of around USD27 million, paid over 15 years;
- Inflation is not considered;
- Interest costs of 6.8% assuming 50% gearing;
- Required return on equity of 15%; and
- The final moisture content of wood pellets is 10% by weight.

Table 8-10 provides an indicative mill door price range taking into account each stage of the manufacturing process based on the inputs described previously. The assessment differentiates between processing residues (which are largely already processed) and logs (which require processing to reduce particle size). The mill door price for woodchips would sit between these two values on account that the moisture content of the woodchips would probably be higher than processing residues, but less than in log form and chipping costs have already been incurred.

Table 8-10: Indicative Capacity to Pay Assessment for Wood Pellet Feedstock

	Mill Door Price (AUD/GMT)	
Residue Source	**Trend Pellet Price USD150/tpe (CIF Korea)**	**Alternative Pellet Price USD200/tpe (CIF Korea)**
Processing residue	37	86
Log (roundwood)	19	59

The results indicate:

- A wood pellet manufacturer has a higher capacity to pay for processing residues compared to logs. This is consistent with international trends where most pellet production is sourced from processing residues;
- A market pellet price of USD150/tonne CIF Korea does not provide a sufficient return to a forest grower supplying logs to cover harvesting and haulage costs. Pellet prices need to be substantially higher, or exchange rates and shipping costs more favourable to provide a positive return to the grower. Based on the assumptions noted earlier in this section, a pellet price of USD200/tonne would be required to provide growers a reasonable stumpage return;
- Any supply from Tasmania becomes marginal if the market price for pellets is below USD150/tonne CIF Korea (assuming an exchange rate of around AUD0.75/USD); and
- Mill door prices are highly sensitive to movements in market price or exchange rate.

Two of the key benefits associated with black pellets are their higher energy density compared white pellets and their hydrophobic tendency. In theory this is supposed to result in significant cost and handling advantages through the supply chain. To date there is little practical evidence available to validate the extent of these savings.

Based on the torrefaction results presented in Table 8-5 Deutmeyer *et al* (2012)[69] estimates:

- Torrefaction produces a net calorific value of ~ 21GJ/t or 16 GJ/m^3 of pellet material
- By comparison white pellets would yield ~17GJ/t or 10.7 GJ/m^3.

This equates to black pellets transporting:

- 23% more energy for the equivalent weight, or
- 37% more energy for the equivalent volume.

[69] Deutmeyer M, Bradley D, Hektor B, Hess RJ, Nikolaisen L, Tumuluru, J, Wild M (2012) Possible effect of torrefaction on biomass trade. IEA bioenergy task 40: Sustainable International Bioenergy Trade

These savings were applied across the entire supply chain assuming black pellets were sourced from the US and exported to Europe. The analysis incorporated all weight and volume benefits, with no additional costs. This resulted in a total saving of 28% or USD23.57/tpe from a typical cost of USD84/tpe. On a CIF sale basis, the savings equated to around 26% with shipping savings accounting for 90% (24%) of the benefit.

When these savings were applied to the pellet mill model assuming a 20% increase in capital and operating costs, and a market price of USD150/pte there was little difference between black and white pellets. However, end markets should have a greater capacity to pay for black pellets as it also gets benefits from improved handling and more energy per unit of feedstock. A price premium of 20% to USD180/pte would effectively double the capacity to pay for processing residues.

Pathway for Residue Utilisation

Market demand for pellets in Tasmania is relatively minor with limited scope for wholesale replacement of existing heating methods, particularly firewood. Small scale opportunities may exist where new pellet facilities can be established in close proximity to an existing sawmill or veneer mill and a major urban centre. This scenario would utilise small volumes of low cost processing residue that currently have limited end markets.

International market demand for wood pellets is expected to expand through renewable energy policies promoting the use of biomass to reduce GHG emissions. A high level financial analysis indicates there is potential for Tasmania to supply North Asian markets under certain market conditions. This would support the development of large scale, export oriented pellet mills. However, Tasmania would not be a low cost supplier to these markets and would need to focus on other elements such as product consistency and volume of supply to expand its market share.

Sufficient fibre is spread across most sub-regions to support the development of multiple large-scale pellet plants. The strongest prospects would satisfy the following requirements:

- Access to a large volume of processing residues, with single sites preferred; and
- Reasonable proximity to a deep water export port to minimise handling costs.

An analysis of end markets and delivered fibre costs indicates wood pellet producers would have a clear preference to utilise processing residues. These are easier to process into wood pellets than roundwood and are often more economic to secure being a byproduct of the timber manufacturing process.

Processing logs into pellets is unlikely to be viable at market prices of less than USD150/tpe CIF unless exchange rates and shipping costs are highly favourable. A market price for white wood pellets of around USD200/tpe CIF is required before log residues would be considered as a potential feedstock to a pellet mill.

Black pellets offer some important benefits over white pellets, most notably a higher energy density and no blending limits when co-firing with coal. However, the technology remains at a formative stage. Despite a number of years of research commercial production of black pellets is still at a prototype/demonstration plant scale. Demand for black pellets may increase, particularly with policy actions that aim to reduce coal consumption.

Table 8-11 provides a summary of the key considerations for further development of the wood pellet sector.

Table 8-11: Summary of Key Considerations for Wood Pellet Development in Tasmania

Criteria	Key Considerations
Key Success Factors	Comparable shipping distance to other key pellet suppliers such as Canada Existing shipping network capable of handling partial shipments NE and NW regions – existing chip handling infrastructure is in place and aligns well with pellet supply chain requirements.
Key Challenges	Cost competitiveness compared to alternative suppliers, particularly from South East Asia Regulated pricing limits potential for price growth over time No static chipping capacity in the SE and new pellet handling facility would be required, most logically out of Hobart Port Covered storage essential for white pellets with capacity to tie into existing chip loading systems Limited capacity to pay for residues and exposure to international currency and shipping markets
Barriers to Entry	Product environmental credentials for pellets sourced from native forest fibre Scale of supply – processing residues most viable option at current prices Supply cost needs to align with regulated prices
Collaborators	Japanese trading houses with existing supply chains Direct engagement with GenCo's/ pellet traders
Competitors	Alternative power suppliers Domestic and international wood pellet providers Alternative fibre users (mainly pulp producers)
Policy Considerations	International – demand will be driven by renewable energy policies which are subject to regular reviews R&D – support development of biomass testing to confirm suitability/ benchmark against competitors Carbon pricing – makes the supply of pellets more competitive with coal
Potential Timeframes for Further Development	Pelletising technology is already well developed. Upgrading of port infrastructure a key barrier especially for supply from southern Tasmania Demand for black pellets will be led by policy development, most likely out of Europe, but may extend to countries such as Japan and Korea over time. Technical challenges suggest that unless there is a technological breakthrough in black pellet manufacturing, increased supply is at best a medium term (> 3-5 years) prospect

9. EVALUATION OF PROSPECTS FOR RESIDUE UTILISATION IN TASMANIA

The Stage 2 analysis of Tasmanian residue utilisation opportunities focused on six processing options. These six potential markets arose from a shortlisting process completed in the Stage 1 review.

The utilisation processes can be broadly classified into traditional wood products and emerging wood fibre uses. This classification provides an insight into the familiarity of the production processes and the market acceptance of the alternative products.

The six options considered for Stage 2 were:

1. Plywood production
2. CLT and glulam production
3. Electricity generation from bioenergy plants
4. Cogeneration of heat or power
5. Drop in hydrocarbon biofuels (liquid transport fuel production)
6. Wood pellet production for domestic or export markets.

This chapter summaries the findings from the Stage 2 analysis highlighting the prospects for each option and its potential to utilise the available residue volume.

9.1 Criteria Analysis of the Options

The Stage 2 report highlights the key considerations for each option in terms of existing market demand, the prices paid for the existing supplies of these products, an indication of capacity to pay for residue fibre and then key timing aspects to the further development of each option.

Given the wide suite of markets, competing products and supply chain arrangements, the Stage 2 report summarises the merits of each option according to the following criteria:

- Key success factors
- Key challenges
- Barriers to entry
- Potential collaborators
- Potential competitors
- Policy considerations.

Each chapter describes these criteria in detail, while Table 9-1 provides a summary of the core components of the criterion analysis, and merits and challenges of all options.

Residue manufacturing processes to produce traditional wood products (pellets, plywood, glulam) are generally well understood and feature relatively established technologies. For these options a common key challenge is proving a Tasmanian product would be competitive in the end markets in terms of functionality and cost. Barriers to entry vary from assessing the technical suitability of products made from Tasmanian residue species or development of infrastructure that would provide an efficient route to market.

For the emerging wood products (in an Australian context) of CLT, drop in hydrocarbon biofuel, bioenergy or cogeneration, the core success factors depend on gaining market acceptance for these products. In these cases, the options produce products that will be competing with established non-wood products such as steel and concrete construction, fossil fuels or power generated from hydroelectricity, natural gas or coal. These existing non-wood products have well established cost structures and have long operated in the market establishing pricing norms for the respective product. The success of these residue processing options will be influenced by their ability to provide a real alternative to the existing non-wood products.

Table 9-1: Summary of Key Considerations for Stage 2 Options

Criteria	Plywood	CLT/Glulam	Bioenergy	Cogeneration	Drop in Hydrocarbon	Pellets
Key Success Factors	Existing processing knowledge	Existing feedstock of suitably valued timber	Mature technologies and sufficient resource for large scale facility	Ready technologies and residues proximity aligns to potential locations	Seamless integration with existing fuel supply chain infrastructure Potential to use large volume of residues in alignment with Tasmanian fuel needs	Well positioned supplier with existing complementary regional port infrastructure Potential to use large volume of residues
Key Challenges	Quality of plantation grown *E.nitens* Competing in international markets against low cost producers	Market development required for CLT/ glulam, including technical product testing Building standards for use of CLT	Cost competitiveness relative to conventional electricity and other renewables	Achieving sufficient scale Uncertainty over gas prices	Technology proven but not currently commercialised	Cost competitiveness and mitigation of exposure to misalignment between price volatility and production costs
Barriers to Entry	Log quality – unproven in an Australian context Capital costs for a greenfield facility	Building standards and proof of product specifications	As above	Capital cost for biomass CHP plants	Acceptance to the use of native forest residues for energy Capital costs of several billion dollars for greenfields opportunity	Aligning operational scale with alternative feedstock cost structures
Collaborators	Existing producers – further expansion of production base	Property developers, builders and architects in residential and non-residential markets Domestic sawmillers	Major engineering contractors and equipment suppliers	Users of natural gas to generate process heat Wood processors with limited residue markets	International proponents offering licensed technology and existing fuel delivery arrangements	Potential to align with Japanese and Korean trading houses

Criteria	Plywood	CLT/Glulam	Bioenergy	Cogeneration	Drop in Hydrocarbon	Pellets
Competitors	Hardwood pulpwood and log exporters competing for log supply Existing domestic producers and importers	Existing CLT/ glulam producers and importers Steel and concrete producers	Electricity from local wind and hydro and via the Basslink undersea cable	Natural gas and grid electricity producers	Existing fuel suppliers Alternative technologies (e.g. electric or hybrid vehicles)	Alternative wood pellet providers and alternative fibre users
Policy Considerations	Nothing specific identified	Consider the impact associated with a wood first policy	Federal government policy already provides support for renewable electricity generation	No national scheme exists for renewable heat State government has the capacity to facilitate potential pan-sectoral opportunities within Tasmania	Extension of the federal fuel subsidies to include hydrocarbon biofuels	Directly influenced by international renewable energy and carbon pricing policies
Potential Timeframes for Further Developments	Medium term - further trials required to confirm viable peeling/drying techniques and appropriate end uses	Medium term - R&D investigating feasibility of producing hardwood CLT and performance against softwood CLT Short term -hardwood glulam already in the marketplace	Medium to long term - no immediate opportunities identified Dependent on timing, location and scale of upgrades to the Tasmanian electricity network	Short term - uncertainty over future gas prices expected to prompt large, stable users to consider alternatives over next few years	Longer term - commercialisation of technology over next 5-8 years and feasibility and business case studies	Short term - commissioning approval and investment processes for port infrastructure

The prospects for each of the six options actually being developed can be assessed by weighing up the following:

- The challenges to securing market acceptance and market access for the finished product;
- The estimated cost of production and in turn the competitiveness of the product given established behaviour of the markets regarding price and quality;
- The status of the product development technologies and product standards developments; and
- The potential for a new processing investment to successfully address a detailed feasibility analysis and related business investment case.

With these perspectives, the six options can be generally assessed to their prospects according to the following rankings:

➢ Highest prospects	Wood pellets
	Glulam
➢ Moderate prospects	Cogeneration
	Plywood
	Bioenergy
	CLT
➢ Lowest prospects	Drop in hydrocarbon

9.2 Potential Impacts on Residue Utilisation

This study sought to identify potential options for utilising Tasmania's forest and wood processing residues. Residues arise from existing wood processing such as sawmilling, plymills or woodchip production, from pulp logs sourced directly from forests and plantations, and from other stemwood currently not utilised in traditional wood product supply chains.

The analysis indicates the statewide residues could total close to 6-8 million tonnes/year. Part of these residue flows are utilised by other wood processing supply chains, most notably in being exported as woodchips for pulp and paper production in North Asian countries. Like many commodity markets, this supply chain experiences periods of strong commercial viability and times when the supply chain faces significant challenges to provide a reasonable return to the respective investors.

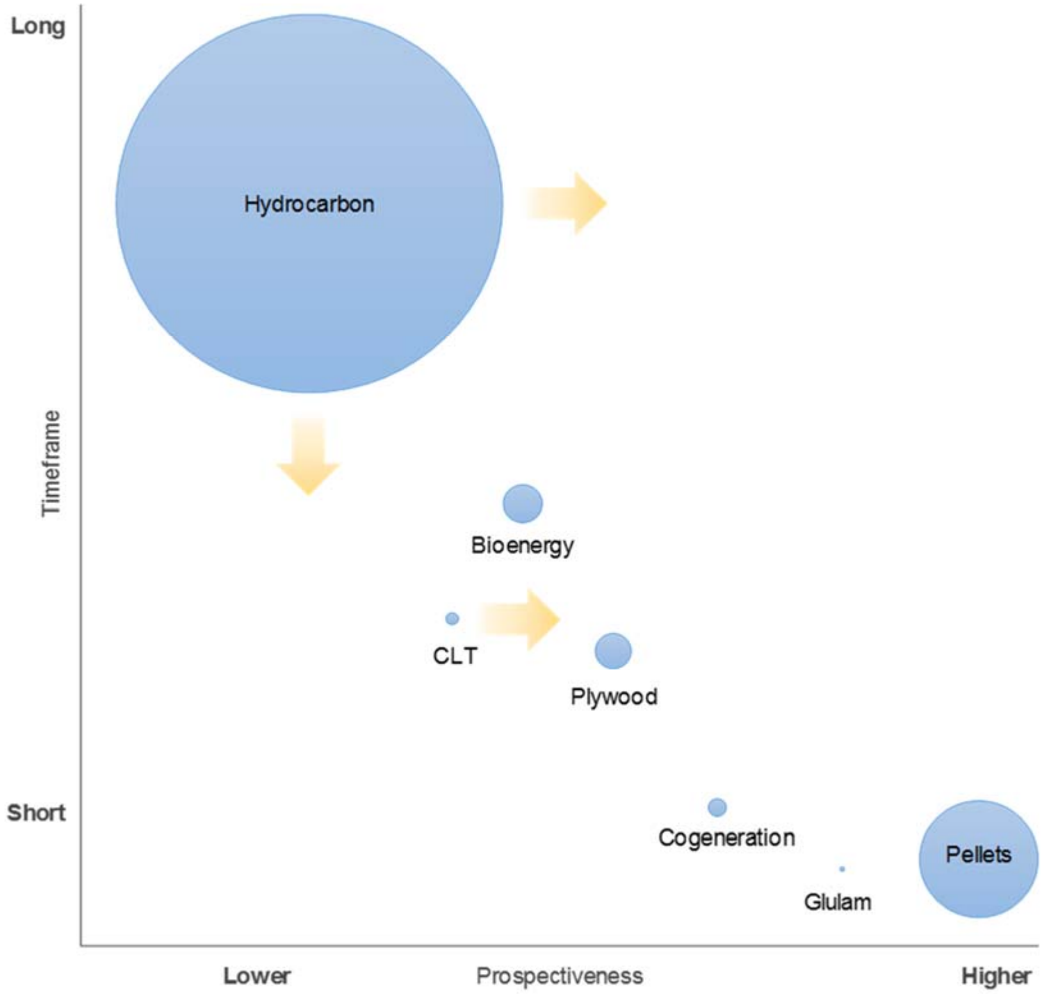
Given these variations, product diversification has the potential to mitigate some of this supply chain risk and may be attractive to industry participants in particular circumstances. However the level of potential residue use for each of the six options are significantly different.

The six options also have differing development pathways and related timeframes. These vary due to differing elements including the timing and control of technology developments, developing product standards that meet market regulations or accepted practice, complexity of business case analysis and infrastructure design and approval.

Figure 9-1 illustrates where each option is indicatively positioned at this point in time. The options are assessed according to their prospects for implementation (from low to high prospects), the likely timeframes for implementation (from short to long) and the size of the option reflects its relative potential to utilise the forest residues available in Tasmania.

The figure also indicates the direction each option may move towards as either technologies or standards advance.

Figure 9-1: Potential Prospects and Timeframes for Each Option



9.3 Benefits for Tasmania

Utilisation of forest residues in Tasmania has traditionally been largely dependent on the export of woodchip for pulp and paper production in Asia. From 2009, for a variety of reasons this export trade declined considerably. The trade of plantation woodchip exports is now increasing rapidly and, given current market conditions and the plantation owners stated intent, is likely to continue particularly from plantations located in the north of the state.

Forest residues arising from native forests directly or via processors, or plantations in the south of the state are currently available for utilisation. The state government is currently exploring the level of private sector interest to increase the utilisation of these residues.

Increasing forest residue utilisation has the potential to improve the viability of the forest sector through increased efficiencies in production costs, and increased utilisation of the fibre by participants along the supply chain.

The options reviewed by this study provide a range of opportunities for the Tasmanian economy. These opportunities include:

- Diversification of end uses and therefore differing market risks compared to existing markets (i.e. wood pellets), which in turn provides the potential to reallocate supplies between markets depending on the competitive positions of Tasmania in respect to market changes;

- Building on existing Tasmanian expertise, and capitalising on the insights of the sector (i.e. plywood, wood pellets);
- Providing alternative power and heat generation sources to the non-forest sector participants (i.e. bioenergy, cogeneration) which can help them mitigate price and supply risks, and well as provide greater direct control over their energy needs;
- Reduce reliance on external suppliers and establish a basis for a broad based Tasmanian energy policy with greater contributions from renewable energy source (i.e. drop in hydrocarbons); and
- Development of new expertise in the state (i.e. CLT, glulam) and reinforcement of the existing processing industry by provision of increased timber product uses.

9.4 Enabling Factors

The diversity of the options indicates enabling factors are also of varying source and potential. Enabling factors can be expected to arise from private sector investment and development, as well as actions from international governments, the Australian federal government and the Tasmanian state government.

These factors include:

- Commercial development of technologies (i.e. in drop in hydrocarbon product commericalisation). These developments are more likely to occur internationally, given the proponents involved and potential applications of such technologies;
- Standards development and code realignments which would assist the prospects of CLT or glulam uses. These could be led by private sector investment or with a degree of support from public sector financing where interests are appropriately aligned;
- Research and development investments from both public and private sector sources, such as exploration of potential black pellet developments or feasibility testing of peeling Tasmanian plantation hardwoods;
- Policy developments relating specifically to renewable energy policies (both internationally and federal governments), carbon emissions policy (internationally and federal government), wood procurement policies relating to construction (state and local governments); and
- Opportunity assessments where multiple contributing factors support a public or private sector investment.

These enabling factors will be controlled and influenced by a range of private sector and public sector stakeholders. The role of government therefore includes maintaining a watching brief on developments in the sector and be able to assess and respond with appropriate government support. Similarly, private sector stakeholders will continue to assess market opportunities, their relative strengths and competitive positions, and capacity to capture an economic gain in expanding their operating arrangements.

9.5 Timeframes

The timeframes and development pathways for each of these options differ, and will change in the future due to a range of influences including new product developments and market signals. Figure 9-1 provides an indication to the current relative timeframes envisaged for each of the options. This indicates some options could be realised relatively quickly, given characteristics such as pre-existing technologies or established market norms. Other options could take significant time to be realised, due to aspects such as technological developments (i.e. hydrocarbon biofuels) or alignment of investment parameters (i.e. bioenergy).

The assessment of timeframes and commercial realization will need to be updated to confirm the speed of development in these various options.

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