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Agriculture & Investment Services
Ministry for Primary Industries
Manatū Ahu Matua

Marlborough's Future is Durable

A regional development case study on the potential for a durable hardwood industry

Part One: Regional Case Study Report

MPI SLMACC 406896 Report No: 3.1

Ministry for Primary Industries Technical Paper No: 2024/16

Prepared for Ministry for Primary Industries

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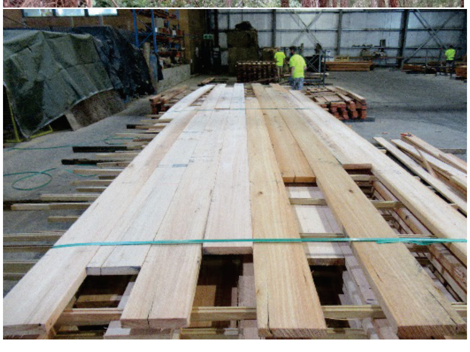
ISBN No: 978-1-991308-32-0 (online)
ISSN No: 2253-3923 (online)



June 2024

Te Kāwanatanga o Aotearoa
New Zealand Government

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Acknowledgements
The authors thank the following people for their contributions to this report and to the SLMACC project:

1. **University of Canterbury School of Forestry**
   Dr Cong (Vega) Xu, Dr Ning Ye, Associate Professor Clemens Altaner, Dr Monika Sharma, Meike Holzenkampfer, Alex Chamberlain, James Burns, Thomas Copeland, Seb Lallemant, Christophe Robert and Georgia Kennedy
2. **Marlborough Research Centre – staff and contractors**
   Gerald Hope, Susan Foster, Kevan Buck, Ruth McConnochie, Roger May, Ash Millen, Tony Pruden, Alex Lloyd
3. **NZDFI case study landowners and trial site hosts**
   Fraser and Shelley Avery, the Dillon family, Gary Fleming, Robert Holdaway, Andrew and Ngaire Lawson, Rob Martin, Robb Macbeth, Marlborough District Council, Marlborough Regional Forests (Phil Woodward)
4. **Marlborough District Council**
   Pere Hawes
5. **Ministry for Primary Industries**
   Sonya Hunt, James Gorrie
6. **Energy Efficiency and Conservation Authority**
   Oliver Howitt

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Executive Summary

This case study reports on the regional development potential for a durable hardwood industry in Marlborough that could produce over $90 million in GDP based on 5,000 ha of sustainably managed eucalypt forests established between 2025 and 2055.

New Zealand Dryland Forests Innovation has undertaken this study to promote a new regional hardwood forestry and wood processing supply chain that could diversify the forest industry and generate new investment and employment. This would improve long-term environmental and economic sustainability and resilience for Marlborough's grape growers, farmers and forest growers.

The case study is presented in two reports (Part One and Part Two).

Part One covers the following four broad areas of investigation and analysis:

a. the potential for a sustainable regional supply of naturally durable posts for vineyards; other timber products and markets; and the overall economic contribution to the regional economy, that growing and processing durable eucalypts in Marlborough could generate.
b. the woody biomass residues that could be recovered from harvesting and processing operations to supply solid biofuel to major energy users in Marlborough, including the wine sector, as they switch away from using fossil fuels.
c. greenhouse gas emissions that could be saved by fuel-switching, and that could be offset through carbon sequestration by new eucalypt forests
d. current national and regional policy and regulations associated with forest growing and hardwood processing relevant to case study

Part Two covers a more detailed investigation and evaluation of:

e. individual property case studies: the potential economic and environmental implications of growing durable eucalypts to supply a new industry on four individual Marlborough farm and forestry properties.

Marlborough has potential to develop a new hardwood industry because of:

a. its over 31,000 hectares of vineyards that could be using naturally durable posts to replace copper-chrome arsenate (CCA)-treated posts
b. the extensive area of pine forests in north Marlborough and dryland farmland in south Marlborough, where diversification by landowners could improve long-term regional sustainability and resilience
c. its larger energy-using businesses, including large wineries, who need to switch away from fossil fuels by 2037, potentially increasing regional demand for solid biofuel produced from forest harvesting and wood processing residues
d. the scale and capability of forestry and wood processing sectors and infrastructure in the 'Top of the South' region (Marlborough, Nelson and Tasman)
e. the network of NZDFI trials in Marlborough, providing science-based evidence of potential forest growth and whole tree biomass-production by durable eucalypts in a range of Marlborough environments.

This case study presents an evaluation of the annual hardwood harvest possible from a wood supply catchment of 5,000ha of new durable eucalypt forests to provide biomass to two proposed processing hubs: (i) a medium-scale hub at Kaituna in north Marlborough, and (ii) a small-scale hub at the Riverlands industrial area near Blenheim. Having two hubs will limit travel distances, thereby reducing costs and emissions for biomass coming from the forests and products being despatched.

The 5,000ha wood supply catchment is based on a 40 km radius around the two processing hubs. Within this catchment area planting of around 3% of suitable land is required. Suitable land is defined as Land Use Capability 6 and 7 classes agricultural land and existing pine plantation forests which could be replanted with durable eucalypts following harvest. Planting needs to be staggered over the next 30 years, with an average of 175-220ha established each year in order to create a sustainable harvest. This planting target would require around 250,000 – 300, 000 seedlings annually that can be locally produced.

Three durable eucalypt species (*Eucalyptus bosistoana, E. cladocalyx* and *E. globoidea*) have been selected and two forestry regimes are proposed: (i) a 28–35-year sawlog regime in more productive north Marlborough and (ii) a 20–25-year post regime in drier, less productive south Marlborough.

A total of 3,000-3,500ha of northern durable eucalypt forests is proposed, predominantly by planting *E. globoidea* on radiata pine cut-over north of the Wairau River and in close proximity to the Kaituna hub. Forests of this scale would produce a sustainable supply of sawlogs of around 52,000m^3 logs per year. The hub would produce sawn timber, solid biofuel products, and possibly veneer.

Regional economic and social benefits produced from 2055 are estimated to be $82.5m GDP per year, direct employment of 200 full-time equivalent jobs, and a return on capital employed of 25%.

A target of 1,500-2,000ha is proposed for south Marlborough by planting woodlots and small plantations on dry farmland in close proximity to the Riverlands hub. These could produce smaller logs to supply an estimated 15,000m^3 to the hub each year yielding 500,000 vineyard posts. This could meet 50% of the annual demand by Marlborough's grape growers and deliver $7.7m-$8.8m GDP per year. The Kaituna hub could supply additional posts if market share exceeded this amount. Other products might include solid biofuel products (e.g. pellets, chip), and possibly veneer and essential eucalypt oil.

Markets for a wide range of durable hardwood products in New Zealand are currently supplied with CCA-treated timber and hardwood imports, both of which could be replaced by naturally durable wood from the new forests we envisage. There is significant potential for exports, especially to Australia.

Harvesting and processing operations will generate residues which could be converted into solid biofuel (e.g. firewood, hog-fuel, pellets, briquettes). A solid biofuel supply chain and markets already exist in Marlborough and eucalypt residues could be added to this. The total tonnes of residues generated by whole tree harvesting and the two processing hubs is projected to be 22,450 tonnes/yr, with an estimated value as solid biofuel of $0.9m-2m/yr.

Demand for solid biofuel in the Top of the South is forecast to increase significantly, with a projected new demand from energy users who are required to switch from fossil fuels to alternatives, such as biofuel by 2037. This includes thirteen of the largest energy users in Marlborough (including seven wineries) that consume 141.16TJ of process heat energy/year using fossil fuel. These thirteen energy users currently produce greenhouse gas emissions estimated at 11.8kt CO_2/equivalent/year. 19,650m^3 /yr of solid biofuel would be required for all these users to switch to solid biofuel.

Essential eucalypt oils are an additional bioproduct that could be produced from foliage of *E. bosistoana,* one of the species recommended for Marlborough growers. A small-scale essential oil production business could be based at the Riverlands hub if there was sufficient foliage supply. Essential eucalypt oil is produced commercially from foliage of various species grown in Australia and China.

A review of the regulatory environment in Marlborough indicates that currently there should be no major impediments to planting 5,000ha of durable eucalypt forests or to establish the proposed two new processing hubs. However, there are local regulations and National Environment Standards (NES) plantation forest standards that need to be met. Growers planting new forests on pastoral land could benefit from registering for the Emissions Trading Scheme in its current form.

The University of Canterbury School of Forestry (SoF) is a NZDFI partner and key science provider. Their long track record of research for NZDFI provides the foundation for this case study in four fundamental areas:

a. tree breeding and propagation
b. site optimisation, forest measurement and growth modelling
c. forest health and biodiversity
d. wood science, processing and products.

For this case study, SoF work involved measurement and destructive sampling of durable eucalypts in NZDFI's Marlborough trials to estimate total above ground biomass and the novel use of drone-based LiDAR to estimate total tree biomass. Project data were analysed along with other trial measurements held in the NZDFI database. Tree and stand level models have been developed that estimate total biomass production for *E. bosistoana* and *E. globoidea* in Marlborough. These are the first regional models for durable eucalypts that have been produced.

This project was made possible by working with four NZDFI landowners with environmentally contrasting but typical Marlborough farm/forest sites who are already growing *E. bosistoana* and *E. globoidea* in trials and/or in small commercial plantations.

Four individual property case studies were undertaken to assess the potential of each property to grow and market durable eucalypts based on their land type and proximity to one of the two processing hubs. The extent to which existing and new planting could offset greenhouse gas emissions from their land-based activities and the financial benefits which could be derived under current ETS rules were also evaluated. The outcomes of the case studies would inform other landowners in Marlborough. The individual property case studies are presented in Part Two of this report.

The completion of the Marlborough regional case study provides a market- and science-based pathway for developing a sustainable durable hardwood industry and supply chains. The results highlight that developing a durable eucalypt supply chain will require long term regional planning, collaboration and investment in planting genetically improved trees by landowners through to processors marketing durable hardwood products. The study provides evidence that a durable hardwood industry could diversify the region's economy; deliver financial and environmental outcomes to farmers, forest owners, grape growers and wine makers; and create new employment in the forestry and wood processing sectors.

NZDFI has also identified many North Island regions that have potential to grow durable eucalypt forests and where further regional case studies could be undertaken.

1 Introduction

Marlborough is New Zealand's leading wine producing region with the area of established vineyards in 2023 of over 31,700 ha and increasing annually. These vineyards use millions of copper-chrome-arsenate (CCA)-treated radiata pine posts and generate substantial carbon emissions both in the vineyards through maintenance & harvesting and subsequently by wine making, cellaring, freight and sales. The Sustainable Winegrowing New Zealand certification programme (SWNZ) has a 'target to be carbon neutral'[1] and a 'target for New Zealand's wine industry to achieve zero waste to landfill by 2050'[2].

Marlborough grape growers need around 19 million CCA-treated vineyard posts with industry estimates of 3-5% annual breakage during harvesting. This equates to a regional demand for over half a million replacement posts each year, with further demand from establishing new vineyards. The broken posts are a significant part of Marlborough's hazardous waste stream, often stock-piled in vineyards, creating an environmental liability. Some are recycled but many tonnes are disposed of annually into the regional landfill.

Moreover, landowners in southern Marlborough (and other drier eastern and northern regions of New Zealand) face increasingly frequent and severe droughts or cyclonic rainfall events so another option to diversify their land-use could improve economic productivity and environmental resilience. Radiata pine forest growers in the region may wish to diversify rather than replant pine given long-term market and environmental challenges currently impacting the viability of the pine forest industry.

Growing eucalypts that produce durable hardwood offers a novel forestry system that could produce logs for regional processing of posts for vineyards and sawn timber for a wide range of other applications. If these forests are planted at sufficient scale to create a sustainable regional supply, then this could significantly reduce and perhaps eliminate the use of CCA-treated posts.

In 2008, the New Zealand Dryland Forests Initiative (NZDFI) was established in Marlborough as a collaborative tree breeding and forestry research project[3]. NZDFI's inception was driven by the opportunity to substitute CCA-treated vineyard posts with naturally durable hardwood posts and the opportunity this offered for local dryland farmers to diversify[4].

NZDFI selected a group of eucalypt species that had potential to deliver these opportunities. These species are fast growing, drought-tolerant, and produce strong, naturally-durable hardwood which can be used in outdoor applications without chemical treatment. However, no large-scale eucalypt forests have yet been planted in the region.

Over the past 15 years NZDFI has successfully undertaken a multi-million-dollar collaborative research, development and extension programme with the support of industry and government. NZDFI's focus has been on planting and assessing a network of over 40 breeding and research trials to determine how these new forestry species can deliver the maximum economic and environmental outcomes to growers. This includes 15 trial sites in Marlborough established in collaboration with eleven innovative landowners, including forest owners, farmers and vineyard owners, the Marlborough District Council and Marlborough Regional Forests.

NZDFI's breeding programme has now produced genetically improved eucalypts for plantation forestry regimes that will produce logs for regional processing of posts and sawn timber and yield additional biomass for biofuel and bio-chemicals. Durable eucalypts are also eligible for carbon credits when planted on ETS-eligible land (see Section 3.7.4).

In 2020 the NZDFI launched its vision for up to 60,000 hectares of durable eucalypts to be planted by 2050 in 12 regional wood supply catchments in northern and eastern New Zealand, creating regional

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[1] Climate Change | New Zealand Wine (nzwine.com)
[2] Waste | New Zealand Wine (nzwine.com).
[3] Millen, P. (2009). NZ Dryland Forests Initiative: A Market Focused Durable Eucalypt R&D Project. In Apiolaza et al. (Eds), *Revisiting Eucalypts*, 57-74. Wood Technology Research Centre, University of Canterbury, Christchurch, NZ.
[4] Millen P (2008) *Grow natural capital to develop resilient dryland farm landscapes in Starborough and Flaxbourne, Marlborough* NZ Land Care Trust.

hardwood industries worth up to $1 billion per annum[5]. A potential 5,000 ha wood supply catchment in Marlborough was identified[6], based around a central processing hub in Kaituna.

Then in 2022, MPI approved funding for the Sustainable Land Management and Climate Change (SLMACC) project described here. Its purpose was to evaluate how regional investment in naturally durable hardwood forests could contribute to sustainability and reduce greenhouse gas (GHG) emissions in Marlborough's wine industry through a sustainable supply of naturally durable posts, timber and biomass for bioenergy.

The project scope included landowner case studies; field measurement; LiDAR capture and mapping; destructive sampling and assessment of whole tree above ground biomass to develop species productivity models; investigation of the additional potential for forestry and harvest residues to be used for bioenergy production.

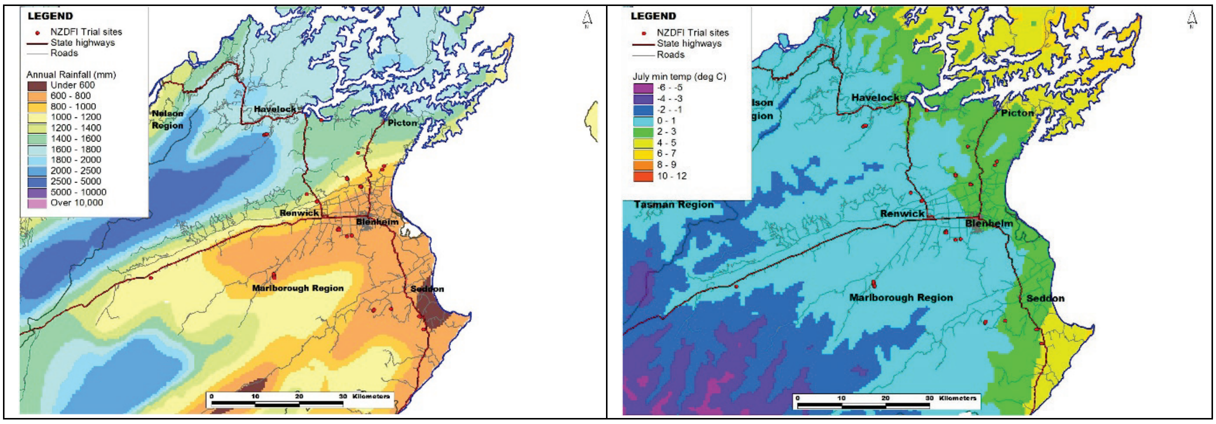
This regional development case study is a major project output. It provides a market and science-based pathway to inform Marlborough landowners and build their confidence to establish new eucalypt forests at a scale that will support a future regional durable hardwood industry supply chain.

While the case study focuses on supplying domestic markets, there is significant export potential for durable hardwood products. For example, the supply of 'native hardwood' in Australia will decrease significantly with the West Australian Government ending the harvest of jarrah forests in 2023 and the Victorian Government ending the harvest of mixed eucalypt forests in 2024. This presents a $400-million market opportunity for New Zealand's forest and wood processing sector.

2 Land use in Marlborough

2.1 Background: historic land use change in Marlborough

Marlborough is a region of climatic and geographical extremes. The southern sub-region comprising the lower Wairau and Awatere River catchments and the coastal zone south of Seddon, have low rainfall, high sunshine hours, and strong winds that create regular droughts. These areas experience moderate winter temperatures with frosts severe in sheltered flat locations but warmer coastal hill country. Loess and young sedimentary soils are typical of this hill country. Further inland altitude, rainfall and winter temperature extremes increase due to the mountain environment. Much of north Marlborough, including the Marlborough Sounds, are mountainous with higher rainfall and milder temperatures. These steeplands are erosion prone due to their low-fertility greywacke and schist derived soils.



Map 1: Marlborough annual rainfall and July minimum temperatures.

Human settlement during the last 700 years has transformed the original forested landscapes. Māori induced fires that converted large areas of the south Marlborough from forest to silver tussock lands, and European settlers accelerated human impacts on the land, draining wetlands, felling forests and burning tussock land to create extensive farmland. In north Marlborough, from the 1850's timber was

[5] https://nzdfi.org.nz/about/strategy-2020-2030/
[6] https://nzdfi.org.nz/grower-information/guidelines-for-growers/regional-strategies/

needed by early settlers who milled the lowland native forests of the Marlborough Sounds and the Pelorus (Te Hoiere) catchment including the Rai, Wakamarina and Kaituna Valleys. The logged-over native forest was then burned and converted to farmland along with large areas of hill country where native forest was felled before burning to create farms. This clearance of native forest for farming continued until the 1970s.

In south Marlborough early farm shelter belt and woodlot planting was underway by the 1890s and a small forest was planted by prisoners in the Awatere Valley in early 1900s. During the 1930s the former NZ Forest Service (NZFS) invested in large scale pine forestry planting beginning in the Rai and Collins valleys and this was extended in the 1960s and early 1970s.Then from 1973 to 1987 the NZFS afforested 16,000ha by acquiring and planting steep farm hill country throughout north Marlborough, with substantial forests planted on the lower slopes of the Richmond Range.

In 1987 the government sold cutting rights to Marlborough's state forests to Fletchers-owned Tasman Forests Ltd. The rights have passed through a number of companies, with current owners One-Forty-One Ltd becoming the owners in 2018. Some of the forests are in their fourth rotation.

The former Marlborough Catchment Board was part of a consortium of local bodies that acquired several large farm properties in the 1970s to plant what is now Marlborough Regional Forests. This consortium is now owned by the Marlborough and Kaikoura councils and manages over 3,500 ha of forests in north Marlborough. Harvesting and replanting started in 1995.

Over this period, investment in pine plantations by farmers was also encouraged by the then Marlborough Catchment Board as a remedy for erosion. The former Marlborough County Council supported this by introducing a rural land subdivision rule that permitted a minimum lot size of 50 ha for a rural property subdivision if used for commercial plantation forestry. This encouraged subdivision and sale of hill country farms for planting by small private forest investors who were supported by NZFS afforestation grants. This initiated a planting boom in the 1970s that continued throughout the 1980s and 1990s. As a consequence, many hill country farm properties in north Marlborough were converted to pine plantations with the flatter land retained for farming or developed as lifestyle blocks. There was a downturn in forestry returns in 2000s but market demand in China, combined with the Emissions Trading Scheme, has seen steady expansion of plantation forests over the last fifteen years.

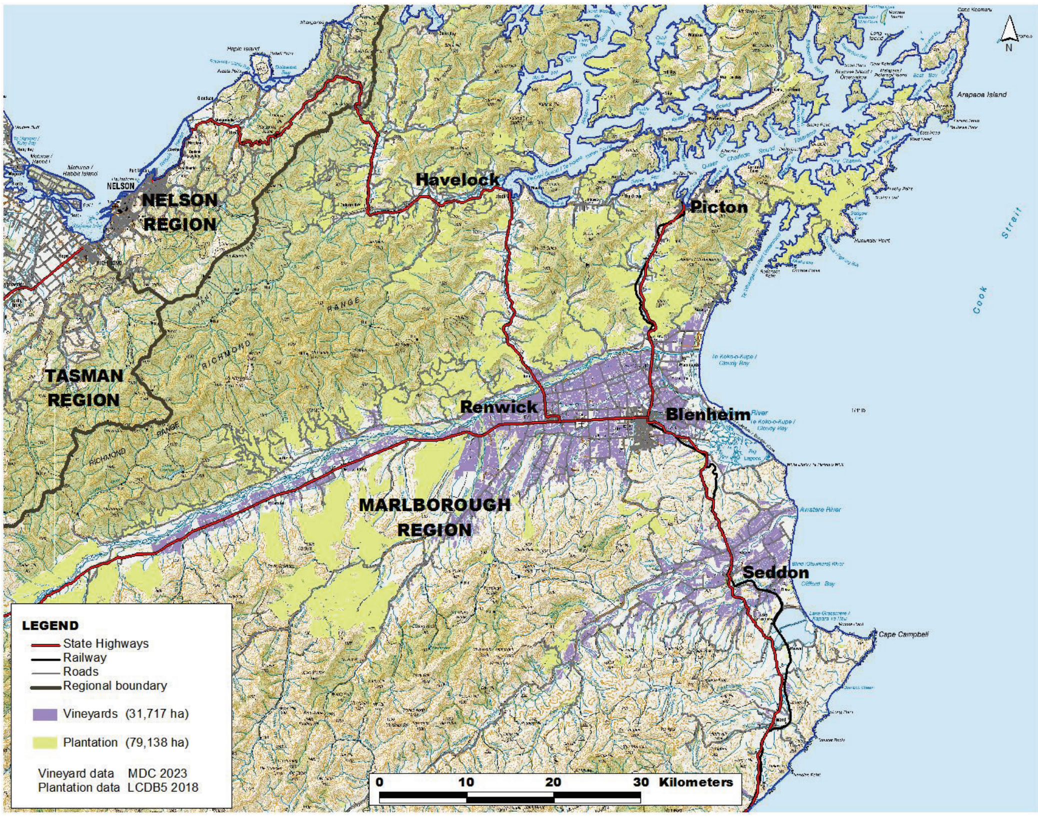
By comparison, Montana (now Pernod Ricard) began the developing a commercial-scale wine industry a little over 50 years ago . This company judged that the region's climate and soils of the lower Wairau Valley provided a suitable terroir for growing high quality grapes. It acquired several large properties and planted its first vineyard in Brancott valley in 1973. As a consequence, another new rule was introduced by the former Marlborough County Council that permitted subdivision of a rural property on the flat and easy farmland (Rural One zoned land) to a minimum lot size of 8 ha for a commercial vineyard. This made it possible for the break-up of many arable, horticultural and stock finishing properties on the lower Wairau, Waihopai and Awatere valleys. These were acquired for vineyard development by a mix of larger corporates and smaller private wine growers. While much of the early planting was with Müller-Thurgau, other varieties were tested including Sauvignon Blanc. Once this started producing international award-winning wines in 1986, most grape growers replanted with this variety and it rapidly become the dominant varietal for which Marlborough is renowned.

The Marlborough Research Centre (MRC) was founded in 1985, ensuring early support for Marlborough's wine industry. The MRC encouraged regional innovation, led by science, and supported industry wide collaboration. This continues today with the Bragato Institute established in 2017 and new facilities opened at MRC's campus in 2021. This regional capability continues to encourage new investment in vineyard development: its work underpins Marlborough's success in New Zealand wine producing internationally award-winning wines.

2.2 Marlborough's current forestry and wine industries

2.2.1 Marlborough's forest industry

Marlborough's total productive plantation forest area in 2022 was estimated to be over 79,000 ha, occupying 7.6% of the region's productive land area. Forestry plantations are predominantly planted on poorer quality, steep hill country, especially north of the Wairau River (Map 2). Radiata pine makes up over 95% of the planted area followed by Douglas fir at close to 3% with small areas of cypresses, eucalypts and other softwood and hardwood species. Australian-owned One-Forty-One owns roughly one quarter of the plantation area and there are 230 other forest owners of small to medium scale forests.



Map 2: Location of Marlborough's plantation forests and vineyards.

In 2023, 719,974 m^3 of logs were exported from Picton (via Port Marlborough) and a further 383,300 m^3 of logs were processed in the Nelson-Tasman region. One-Forty-One's sawmill at Kaituna is the largest processor in Marlborough, with an intake of around 110,000 m^3 of logs annually, and that includes some logs from the Nelson region. There are two other much smaller sawmills in Marlborough but many logs are processed in Nelson's multiple sawmills, wood processing and remanufacturing companies, or exported via the Nelson port. This inter-regional combination of multiple supply chains creates a successful single Top of the South forestry and wood processing sector. In 2021 Statistics NZ reported that across both regions there are over 550 FTEs employed in forestry, and over 1600 FTEs in wood processing[7].

The inter-regional supply chain for other forestry species except Douglas-fir is very small scale by comparison. There are a few small scale sawmillers and wood processors that utilise various specialty timber species and local mobile sawmillers who can saw timber for growers to use or sell. Some logs are exported.

The sector contributes significantly to the regional economy and employment. Like all other industrial activities, there are environmental standards to meet and good business practice needed to maintain the sector's social licence to operate. The authors consulted the Marlborough District Council about the implications of the regional regulatory controls affecting the forestry and processing proposals described in this case study and their feedback is included in Section 3.7.

2.2.2 The Marlborough wine industry

Marlborough is New Zealand's largest producer of wine with two decades of expansion increasing vineyards from 6,831 hectares in 2003 to 31,717 hectares in 2023 (Map 2). In 2023, the region produced almost 400,000 tonnes which is 78.6% of the national grape harvest. Total wine sales in 2023 were 266 million litres with a total sales value of $2.1 billion. The industry body 'Marlborough

[7] Te Uru Rakau Marlborough Regional Fact Sheet, April 2024 [Marlborough-fact-sheet.pdf (canopy.govt.nz)](canopy.govt.nz)

Wine' represents 518 grape growers and 160 wine companies that produce over 80% of New Zealand's wine annually[8].

Sustainability is an integral part of the New Zealand wine industry. Launched in 1995, Sustainable Winegrowing NZ™ (SWNZ) is widely recognised as a world-leading sustainability programme. Some 97% of Marlborough's productive vineyard area is certified by SWNZ. SWNZ certifies all parts of the supply chain including vineyards, wineries, bottling facilities, and brands on the basis that members meet guidelines for sustainability practices in the vineyard and winery. Over 90% of the wine produced in New Zealand is processed in SWNZ-certified facilities.

However, Marlborough's vineyards use large quantities of CCA-treated posts and growers need a sustainable alternative post and this is the regional market opportunity identified by NZDFI – i.e. to supply naturally durable timber posts, grown and processed in Marlborough, for the vineyards.

3 The NZDFI SLMACC project – Marlborough regional development case study on the potential for a durable hardwood industry

3.1 Project research objectives and outcomes

The Marlborough regional case study described here was undertaken by a combined team from Marlborough Research Centre, University of Canterbury School of Forestry and the Bioenergy Association of New Zealand, with funding provided by the Ministry for Primary Industries' Sustainable Land Management and Climate Change fund.

The study authors report on the potential for a sustainably managed 5,000 ha durable eucalypt forest to be established in Marlborough and assessed:

(i) the emissions the eucalypt forest resource could offset through sequestration
(ii) the potential sustainable regional supply of naturally durable posts and other timber
(iii) the biomass that could be recovered to supply solid biofuel to the wine sector and other potential bioenergy applications.

To undertake the case study, the NZDFI/UC team advanced some critical research.

1. *To create tree-level models of biomass and carbon storage for two key durable eucalypt species (*Eucalyptus bosistoana *and* E. globoidea*) with improved plot-level growth and yield models that provide accurate estimates of future carbon storage and wood production in Marlborough.*

   This was achieved by measurements of diameters at breast height (dbh) and heights of trees in permanent sample plots, whole tree biomass sampling of trees, measurement of stem dimensions to improve taper and volume functions used in growth and yield models for predicting whole tree biomass of each species. A technical report about this has been submitted for publication[9]. Development and use of these models for this case study is outlined in section 3.3.3.

2. *To evaluate whether drone-based LiDAR data can create more exact and efficient estimates of stem dimensions, biomass and carbon storage of forest stands of* E. bosistoana *and* E. globoidea *than can be achieved with purely ground-based sampling.*

   This was achieved by comparing the results from aerial LiDAR surveys of stands combined with ground-based whole tree biomass sampling. This study established that LiDAR-derived metrics can be used to accurately estimate whole tree above ground biomass enabling a pathway to develop efficient biomass assessment for durable eucalypt plantations. A full report has been submitted for publication[10].

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[8] Marlborough Wine | Region, Visit, Wineries, Events & News (marlboroughwinenz.com)
[9] *Individual tree biomass sampling of durable eucalypts (April 2024)*: Report submitted to MPI as part of this SLMACC project.
[10] *Individual tree biomass estimation of durable eucalypts using LiDAR (November 2023)* Report submitted to MPI as part of this SLMACC project.

3. *To develop four Marlborough farm/forestry/vineyard property case studies based on analysis of greenhouse gas (GHG) emissions and carbon sequestration by existing* E. bosistoana *and* E. globoidea *plantations.*

   The four landowners that participated in the individual property case studies were as follows:

   - The Lawson property (Andrew and Ngaire Lawson) – vineyard owner and small-scale beef and sheep farm in Awatere Valley. Property includes an *E. bosistoana* trial planted in 2009.
   - The Avery property (Fraser and Shelley Avery) – large-scale beef and sheep and cropping farm in Grassmere Valley. The property includes an *E. globoidea* trial planted in 2011.
   - Lowlands vineyard and winery – (Alfa Lea Horticulture including Birch Hill Forestry Ltd) – Holdaway family vineyard and commercial pine forests in Wairau Valley. The property includes stands/trials of *E. bosistoana* and *E. globoidea*, both planted in 2021.
   - Marlborough Regional Forests Pukaka Forest – regional government-owned commercial forest in Pukaka Valley. Pukaka Forest includes stands of *E. bosistoana* planted in 2003 and 2006, and *E. globoidea* planted in 2006.

In collaboration with these landowners we have completed calculations of greenhouse gas emissions for their properties using industry reports, data and models. Estimates of carbon sequestration by their existing eucalypt plantations have been calculated using freely available methods and these are compared alongside the estimates from the new growth and yield models developed under this project.

The individual property case studies are presented in Part 2 of this report.

3.2 Previous NZDFI and other research and development outcomes relevant to this case study

This case study was informed by several research and development programmes undertaken by NZDFI since its establishment in 2008. There have been multiple research and development outputs that are referenced throughout. These outputs have been possible by the investment of the four NZDFI partners, also support of MPI's SFF fund; the MBIE/Forest Grower Research funded Specialty Wood Products partnership (SWP) and NZDFI/Te Uru Rākau-NZ Forest Service's One Billion Trees Partnership.

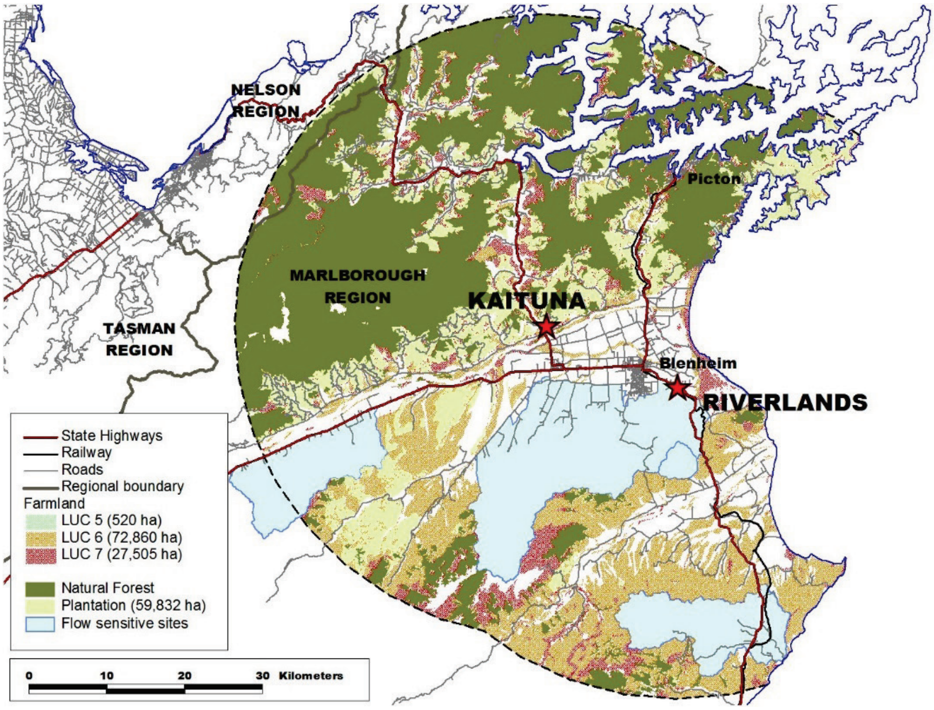
In addition, NZDFI has collaborated with Scion under the SWP and there are references to their research outputs in this case study.

3.3 Developing a durable hardwood supply chain in Marlborough

3.3.1 The vision: 5,000 hectares of durable eucalypt forest supplying hardwood processing hubs in north and south Marlborough

This regional case study describes how the establishment of over 5,000ha of durable eucalypt plantations across the Marlborough region between 2025 and 2055 could create a log supply for two regional supply chains producing durable hardwood vineyard posts, timber and possibly veneer along with forest and sawmilling residues.

These forests could supply two proposed future processing hubs at Kaituna (north Marlborough) and Riverlands (south Marlborough) (Map 3) with a surrounding wood supply catchment based on a 40-kilometre radius around each hub.



Map 3: The case study wood supply catchment proposed with two possible hubs at Kaituna and Riverlands.

NZDFI land-use analysis shows that there are over 100,000 ha of low productivity farmland in Land Use Capability (LUC) classes 5-7 within a 40 km radius of Kaituna and Riverlands (excluding the Afforestation Flow Sensitive Areas, where new plantations are restricted), plus another almost 60,000 ha of existing forestry plantations (Map 3).

5,000 ha of new durable hardwood forests would require only 3.1% of the land suitable for planting new durable eucalypt forests (Fig 1).

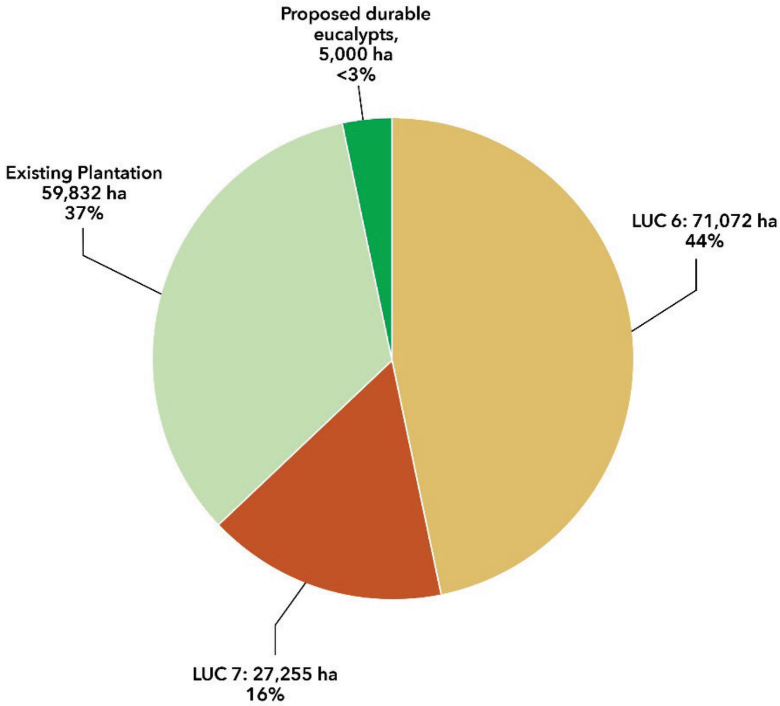


Fig 1: Land use within the two proposed Marlborough wood supply catchments, showing how 5,000 hectares of durable eucalypts would occupy less than 3% of land suitable for planting new eucalypt forests.

The case study authors assumed that Marlborough's forest growers, farmers and other landowners could establish an average of 175-225 ha of new durable eucalypt plantations requiring 250,000 – 350,000 seedlings annually through until 2055. This level of planting is needed to ensure that sufficient volume for an annual post and log harvest is sustainable to produce a long-term log supply. This in turn will ensure that future investment in the two possible hardwood processing hubs is commercially viable.

3.3.2 Developing a durable eucalypt supply chain

The stages involved in developing a future durable eucalypt supply chain are shown in Fig. 2 below:

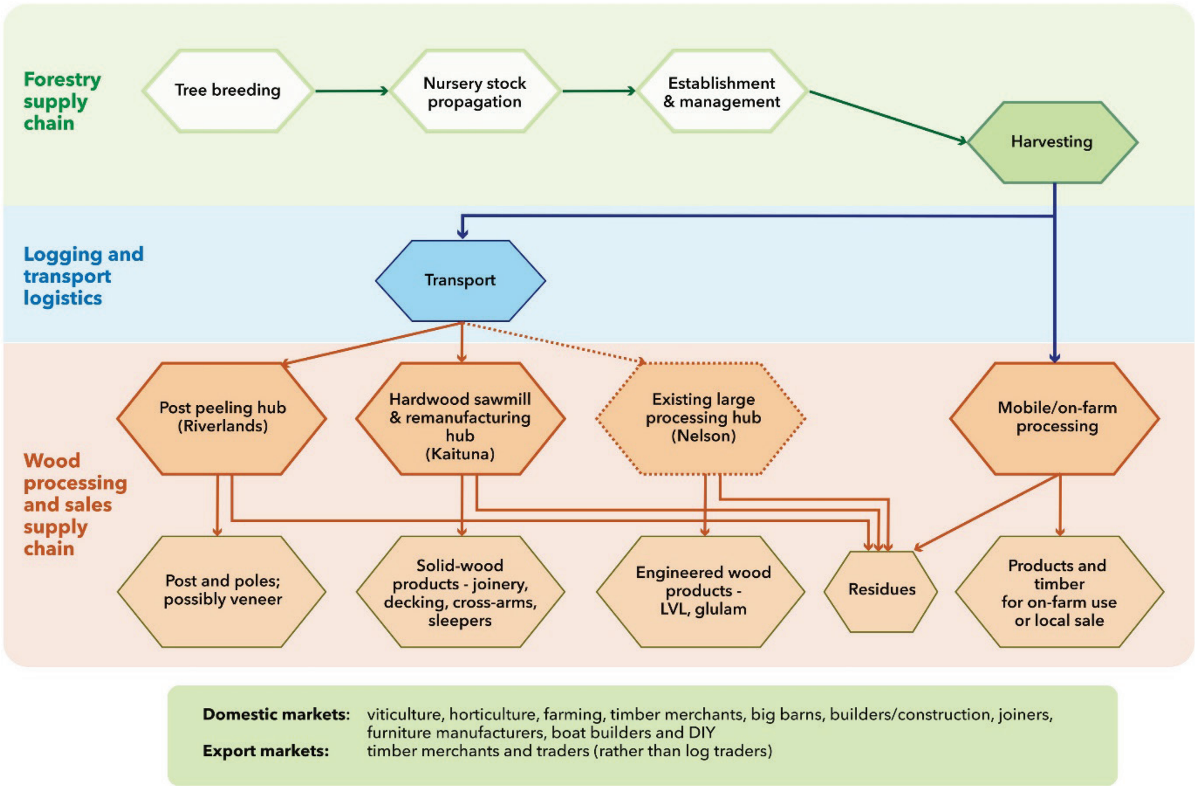


Fig 2: Developing a durable eucalypt supply chain in Marlborough.

As developing a novel forestry and wood processing supply chain involves significant risk and investment, NZDFI has been working for over 15 years on tree breeding, seed production and site species matching that makes it possible for commercial nursery stock to be propagated to establish new forests. This case study provides the opportunity to:

i. describe our market and science-based research that provides the evidence for the potential of a durable hardwood industry
ii. to inform Marlborough landowners and others about this potential
iii. to build confidence to establish new eucalypt forests at the scale needed to support investment in a future regional durable hardwood supply chain.

3.3.3 Durable eucalypt species and forestry regimes suited to Marlborough

3.3.3.1 Parameters for species selection

Eucalypt species that produce durable heartwood evolved across a wide range of diverse environments. In the temperate regions of south-eastern Australia i.e. New South Wales and Victoria, the geographic influence of the Great Dividing Range creates environments similar to parts of New Zealand. New Zealand is a small country with diverse regional environments and selection of a group of productive species with broad adaptability able to match New Zealand sites and produce high durability hardwood is important for success.

In the early 2000s, NZDFI identified 11 species with proven adaptability or potential adaptability for New Zealand's warmer and drier regions, and with proven natural timber durability for high value products and diverse applications (see Section 4 for more details of NZDFI's species selection and breeding work). The species selected for tree improvement have been commercially sawn and processed in Australia with some of these widespread in their natural range, and others with limited distribution. Some are in conservation reserves and no longer commercially harvested.

While all species selected by NZDFI produce durable heartwood, each species has distinct wood properties suitable for different applications. The two main wood properties that influence the potential applications, and therefore the market value and demand for the hardwood produced by these species, are heartwood durability and colour. Timber durability is classified according to an Australian Standard AS 5604[11]: NZDFI's species are all class 1 or class 2 - i.e. the most durable natural timbers. Richly coloured timbers are generally highly valued in overseas markets; durable eucalypt timber colours range from deep red-brown to pink with these colours reflecting each species' wood extractives, which are the natural compounds produced by the tree to confer durability.

Straight natural stem form can vary between species and needs selection. Some species become inherently stout as their height growth declines but not their stem diameter so they have significant taper while other species can grow very tall with slower diameter growth and therefore minimal taper. Taper also changes with age so the timing of harvest influences the log dimensions produced and the options for processing.

Within a stand the diameter and height relationship can also be influenced by: (i) how closely spaced the trees are planted (ii) initial losses and subsequent natural mortality; and (iii) any thinning to reduce competition and encourage diameter growth to ensure the stand reaches an optimal diameter range by harvest age.

The ability to coppice was a trait of interest for selection of species. Thinning of trials have confirmed that all species will regrow epicormic stems from a cut stump. Coppice based forestry regimes could reduce the vulnerability of harvested sites to erosion as the stumps retain living roots that are naturally root grafted together; also, regrowth and site occupancy will be faster than by replanting seedlings. Coppice regimes have been employed internationally for many species for short rotation post and pole production and biomass production. Coppice regimes have never been applied at scale in New Zealand as most conifers including radiata pine do not coppice (coastal redwood, *Sequoia sempervirens*, is an exception). However, the coppice regrowth may require thinning to a single leader to produce a productive stem. Also, chemical control of unwanted coppice regrowth is required when growers plan to replant with improved genetics following a harvest.

Most durable eucalypts flower producing nectar and pollen suitable for honey bees while native birds also forage for nectar along with native insects. Some species flower at times of year when nectar and pollen is otherwise in short supply[12].

3.3.3.2 Suitable species for Marlborough conditions

Three species have been identified as adaptable and productive in Marlborough – *Eucalyptus bosistoana, E. cladocalyx*, and *E. globoidea*:

- ***E. bosistoana*** - **coast grey box**: a class 1 durable species suited to more sheltered sites including alluvial silts/gravels such as river flats and terraces. It is able to tolerate periodic flooding and is moderately frost-tolerant
- ***E. cladocalyx*** - **sugar gum**: a class 1 species able to survive and thrive on very dry, rocky and exposed sites as long as they are relatively frost-free
- ***E. globoidea*** – **white stringybark** – a versatile class 2 species which grows well on a wide range of sites (except those with poor drainage) and is exhibiting the highest growth rates of any species in most NZDFI trials.

Each species has now been proven, through NZDFI's trial network, to be suitable for certain site types. A high proportion of Marlborough land types identified for forest planting are suited to at least one of these three species.

See Section 4 and Appendix 1 for more details of the NZDFI research and breeding programme, and the characteristics of these three preferred species.

3.3.3.3 Marlborough regional variation in the productivity and heartwood of durable eucalypts

The objective of NZDFI's demonstration trials is to assess individual species' performance across varying environmental conditions and compare the long-term adaptability, form and productivity of each species. Repeated measurement of permanent sample plots (PSPs) over the rotation of a forest

[11] Standards Australia, 2003. Revised 2005. AS 5604 – Timber-Natural durability ratings
[12] Eucalypts and Bees - NZ Dryland Forests Innovation (nzdfi.org.nz)

is necessary to fully capture and understand the site characteristics that influence species' performance. NZDFI has established a network of trials that provide the basis for measurement of over 700 PSPs. Regular PSP measurements started in 2014.

Using simple graphic analysis of PSP tree height/age data for NZDFI's *E. bosistoana* trials in Marlborough, the significant divergence in productivity is evident between the north and south Marlborough PSP sites (Fig 3). A similar trend emerges with data from PSPs of *E. globoidea* (Fig 4).

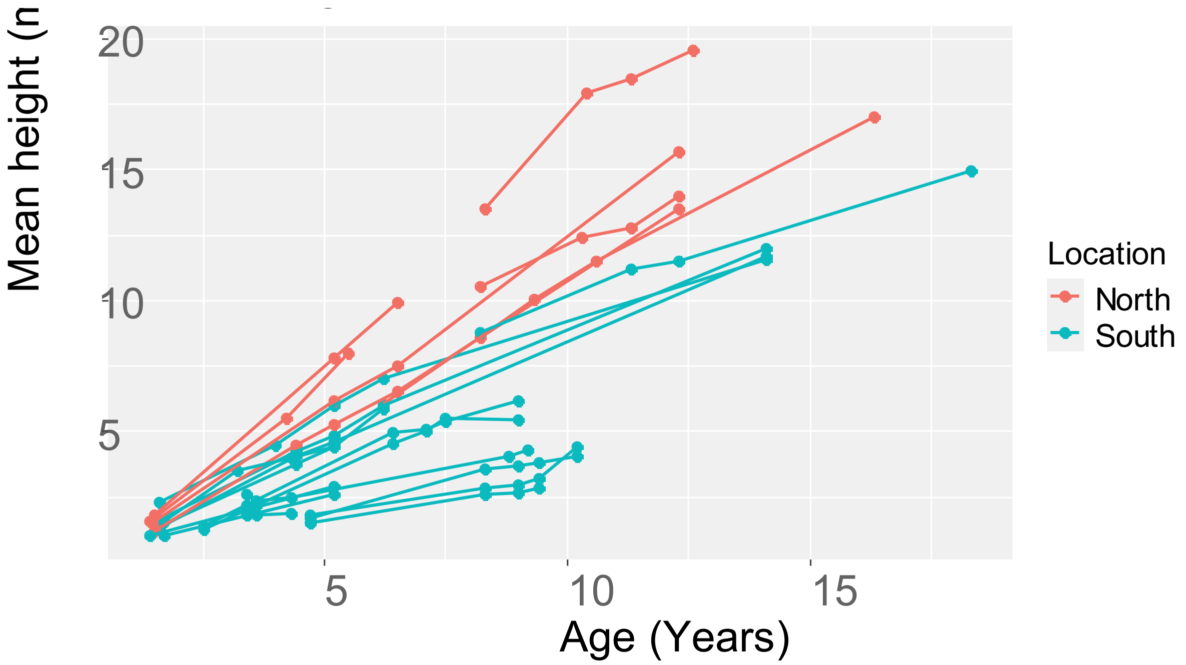


Fig 3: Comparison of E. bosistoana *growth in NZDFI PSP trial sites in north and south Marlborough.*

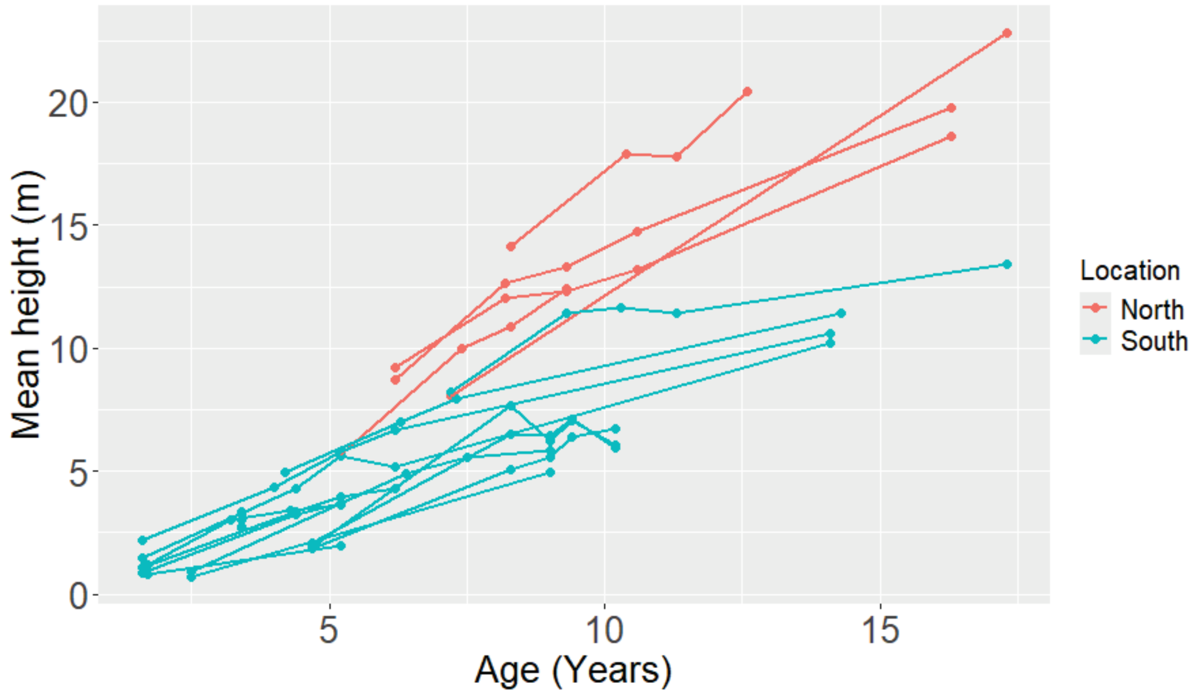


Fig 4: Comparison in E. globoidea *growth in NZDFI PSP trial sites in north and south Marlborough.*

The sub-regional productivity variation demonstrated by these trials highlights the importance of choosing the optimal species and growing regimes for Marlborough. *E. globoidea* is well adapted to north Marlborough's higher rainfall and where planted on pine cutover forestry sites, NZDFI has recorded the highest regional productivity. This aligns with pine productivity variation across the region with north Marlborough radiata pine plantations recording the highest regional productivity. Cut-over pine sites are therefore well suited for replanting in *E. globoidea* following harvest. The current productivity of the *E. globoidea* stand planted on a pine cut-over NZDFI trial site in Marlborough Regional Forests' Pukaka Forest case study site is a good example of this species' potential.

In north Marlborough there are flat and low-lying areas with high fertility soils including alluvial areas prone to frost and periodic flooding or waterlogging that are suitable for *E. bosistoana*. It may be suitable for dairy farms in woodlots and shelterbelts. These sites will have greater productivity than planting steep pine cutover hill slopes.

In south Marlborough, *E. globoidea* can be grown on much of the low rainfall coastal hill country at about 40% of productivity in north Marlborough. The more fertile soils on easy-to-moderate coastal hill country and in frosty, flat alluvial sites prone to periodic flooding or waterlogging will also suit *E. bosistoana*. Preliminary data for *E. bosistoana* indicate that dry, low productivity sites with annual diameter growth of 10-15 mm produce trees with a wide sapwood band but heartwood with high extractives.

Eucalyptus cladocalyx is suitable for exposed dry upper slopes of the south Marlborough's coastal hill country where sites have little frost in winter. NZDFI has tested this species using a genetically improved Australian seedlot. The productivity of this seedlot is proving to be similar or slightly better than the unimproved *E. bosistoana* (Fig 5). (See section 3.3.3.4 and Appendix 1 for more details about *E. cladocalyx*.)

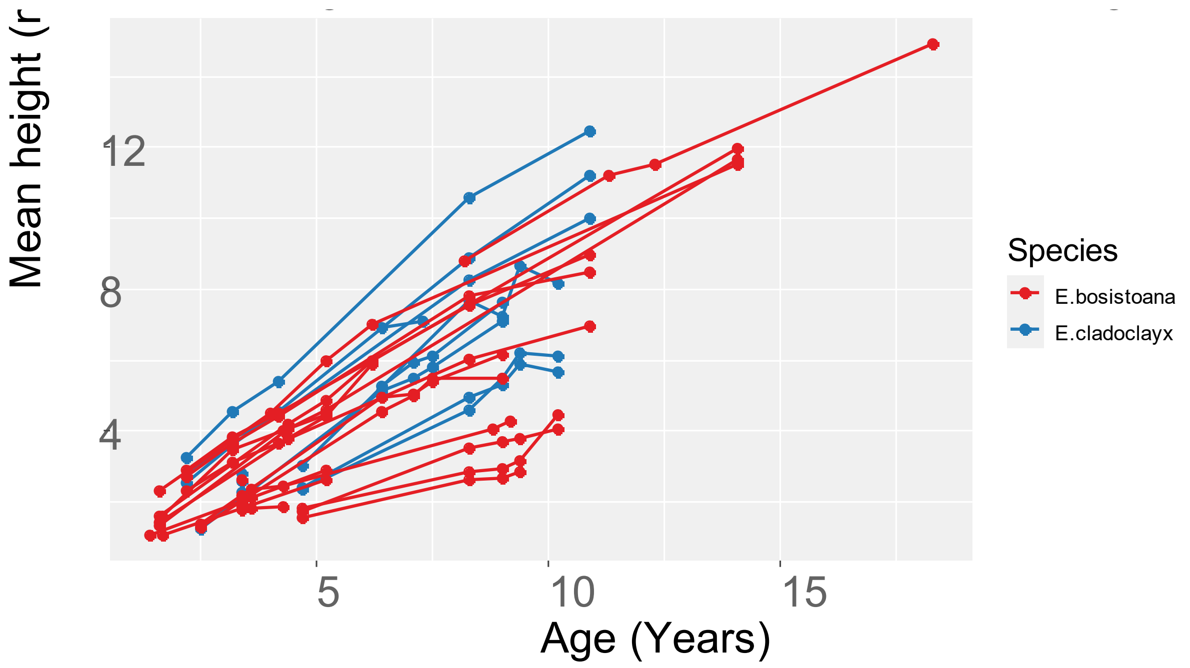


Fig 5: Comparison between E. bosistoana *and* E. cladocalyx *growth in NZDFI PSP trial sites in south Marlborough.*

However, there are extensive inland areas of both north and south Marlborough where none of these species will be suitable due to the harsh winter extremes.

Potential growers need to take this information in consideration when selecting the right sites to grow durable eucalypts. Their forestry regimes will depend on their site locations and environments, and planting forest within the 40 km catchment of the two proposed processing hubs is more likely to ensure success (see Section 3.4).

3.3.3.4 Development of Marlborough regional stand level productivity, heartwood and AGB models for *E. globoidea* and *E. bosistoana*

The key project objective was 'to create tree-level models of biomass availability and carbon storage for two key durable eucalypt species (*E. bosistoana* and *E. globoidea*) with improved plot-level growth and yield models that provide accurate estimates of future carbon storage and wood production in Marlborough'.

This objective required work on developing two types of models so predictions of total carbon (biomass) and wood production are possible. One of these is a single tree level model. The other is a plot or stand level model. The major focus of the SLMACC-funded field work was the destructive sampling of 79 *E. bosistoana* and 33 *E. globoidea* trees that have provided the necessary data required for developing robust regional tree level models for both species.

By comparison, regional stand level models developed for this case study are based on data from regular measurement of permanent sample plots (PSPs) that extend from Northland to north Canterbury. Through a combination of all PSP data with outputs from the regional tree level models, plot (stand) growth and yield models for both species have been developed. These plot level models enable projection in time of mean top height, basal area/ha, and stems/ha. Tree-level models of stem wood volume, heartwood content and biomass were then applied to each measurement of individual trees in PSPs, and relationships between plot-level estimates of these variables with mean top height, basal area, and stand density index were developed so plot level estimates of wood volume, heartwood content, biomass and CO2 sequestration could be included in plot-level model outputs.

However, as most of the PSP data for both species is from young and semi mature stands, the application of the regional plot (stand) level models developed are limited to predictions of 20 years for *E. bosistoana* and 25 years for *E. globoidea.*

The regional stand level model developed for *E. globoidea* significantly builds on the first stand level model developed in 2019 by the University of Canterbury for a durable eucalypt species[13]. The PSP dataset utilized for this included 23 Scion-managed PSPs and only 6 NZDFI PSPs. Scion's PSPs provide data for trees older than NZDFIs as many are located in stands planted in the 1990s and early 2000s. However, these are mostly located in the northern North Island with only one site in the South Island.

The University of Canterbury's next major advance in 2020 was further development of the stand level model by destructive sampling of 74 mature and semi-mature *E. globoidea* trees at 7 sites to collect discs and develop a full stem taper function that breaks down the tree into its component parts i.e. bark, sapwood and heartwood[14]. This was incorporated into the stand level model to develop the first forestry stand level model with predictions for age related stem heartwood volumes.

Throughout 2020 to 2023 a large number of *E. globoidea* PSPs were re-measured in NZDFI's earliest trials planted in 2011 - 2014 and some older Scion PSPs were re-measured. This significantly added to the species PSP database with data from 97 NZDFI PSPs incorporated into the model.

By comparison, there are no older Scion PSPs of *E. bosistoana* as the species was rarely planted in New Zealand until NZDFI commenced research in 2008. Since then, this species has been included in many trials and while there are datasets for 130 NZDFI PSPs, nearly all of these were under 12 years at time of measurement.

Prior to this SLMACC project the only modelling for *E. bosistoana* had been a University of Canterbury project to develop a preliminary bark, sap/heartwood volume and taper model in 2021 by felling 11 ten-year old trees in a NZDFI trial for stem analysis[15]. When the model equations were developed and compared to similar equations created for *E. globoidea* (with a larger dataset and a larger range of tree sizes), it was clear that the two species do not share the same sets of equations. *E. bosistoana* tended to have thinner bark and less heartwood than equivalently sized *E. globoidea*.

The plot-level model development for *E. bosistoana* used only 46 of the 130 NZDFI PSPs, as only 46 had repeated measurements, and consequentially limits its application for predicting growth and heartwood yield much beyond the maximum age of the data set i.e. 20 years. Furthermore, as some

[13] Salekin, S et al (202)) Preliminary juvenile height-yield models for three durable Eucalyptus species by integrating site-specific factors. SWP Technical Report T094, February 2020.

[14] Boczniewicz, D, Mason E, Morgenroth J (2021) Developing fully compatible taper and volume equations for all stem components of Eucalyptus globoidea Blakely trees in New Zealand. SWP Technical Report T134, September 2021.

[15] NZDFI Clonal Propoagation Programme: A preliminary volume and taper model for *E. bosistoana*. E G Mason (University of Canterbury), R M McConnochie and A P MillenJune 20211BT 0495 Milestone Report No: 6. Prepared for 1BT Partnerships | Te Uru Rākau - Forestry New Zealand

of the most rapidly growing PSPs are young it is likely that the current model under-estimates productivity of *E. bosistoana*.

Ongoing stand level model development could be undertaken if the database is increased by regular re-measurement of all existing PSPs and the establishment of new PSPs in suitable stands both in Marlborough and other regions. PSP measurement over the full rotation length followed by pre-harvest and post-harvest inventory would extend productivity predictions to harvest and significantly improve the outputs provided by both current stand level models.

Note: NZDFI has 31 *E. cladocalyx* NZDFI PSPs located across 12 sites including 3 sites in Marlborough. These are planted with 1st generation seed acquired from the Australian Low Rainfall Tree Improvement Group (ALRTIG). These have been measured but model development of this species was not included in this project. In 2023 an Australian 3PG (use of Physiological Principles in Predicting Growth) process-based model model was developed from the measurement of ALRTIG *E. cladocalyx* trials and analysis of site environmental conditions[16]. If access were obtained to the use of this model, then it could be extended to New Zealand through analysis of the NZDFI PSP data sets.

3.3.3.5 Model application and outputs for the four individual case study properties

For each of the four individual case study properties, re-measurement of existing *E. bosistoana* or *E. globoidea* NZDFI PSPs located within various trial blocks had been completed as a part of the 2022/23 summer field work. This data from each site was applied to the relevant model to simulate growth and predict annual increase in total stem volume; heartwood volume; CO2 sequestration; stem biomass and branch biomass. The simulations for each site are presented in Part 2 of this report.

The simulation outputs quantified the significant north/south sub-regional productivity difference and provided the basis for ‘broad brush’ regional case study projections of forest growth and yield for both species under the two regimes described in Section 3.4.

Despite the model’s limitations, the simulation outputs also confirm that *E. bosistoana* produces less heartwood compared to *E. globoidea* at similar ages, regardless of site. As a result, the model predictions at the two case study properties with *E. bosistoana* indicate that the actual stem heartwood volume at harvest is low. However, heartwood development in older trees could increase at a faster rate than the heartwood volumes predicted by the model. There is no published work about eucalypt heartwood formation during tree maturation so this variation between the species can only be studied by further measurement, coring and destructive sampling as the NZDFI trials get older.

3.3.3.6 Predicting gains made by NZDFI’s tree breeding programme

NZDFI’s tree breeding and research programme is based on deploying extensive Australian natural (unimproved) populations of *E. bosistoana* and *E. globoidea* in replicated trials. Some trials are mixed provenance species trials to test adaptability and productivity in many NZ environments. This is where many of NZDFI’s PSPs are measured. In addition, progeny trials have been established to test many families of each species over multiple environments. Stable genotypes have been identified in these progeny trials with minimal genetic x environment variability making it possible to select trees for significant gains in growth, form and wood properties.

In 2021, NZDFI completed trait analyses of 160 families using data from all three *E. globoidea* progeny trials planted in 2011. Breeding values for each open-pollinated family have been calculated and the estimated increase in diameter growth and heartwood ratio of the XyloGene seedlot collected from the top families in these progeny trials against the unimproved control seedlot is 12.2% and 31.1% respectively. The control is a Cann River provenance seedlot which was consistently deployed in the species trials and measured as PSPs. A selection of diverse elite genotypes has been commercially deployed by Proseed in 2018 in a small seed orchard at their Amberley property. Further propagation is being undertaken this year to extend it.

NZDFI’s first breeding population of *E. bosistoana* was established in progeny trials in 2009 with 66 open pollinated families at 3 sites. There has been measurement and wood sampling to identify the top performing families. These have already been grafted and established in a clonal seed orchard by Proseed NZ. The estimated gain from a collection of seed from the top ranked families in this clonal

[16] Trials Review, Information and Genetics (TRIG) Project, Victoria, Australia: https://www.forestry.org.au/victorian-trials-project/
TRIG Final Report: https://www.forestry.org.au/wp-content/uploads/2023/05/TRIG-Final-Report-23-May-2023.pdf

seed orchard compared to the unimproved breeding population is 11.4% for DBH and 22.6% for heartwood ratio.

With both seed orchards producing XyloGene branded seedlots, the genetic gains from NZDFI breeding programme will increase productivity and heartwood percentage over the unimproved trees that have provided the data sets for the models.

Having a secure supply of genetically improved seed makes it possible for these gains to be available for commercial scale seedling production and planting. The seed is sold under the XyloGene® brand by Proseed NZ and a NZDFI royalty charge is collected from nurseries on their seedling sales.

3.3.3.7 Proposal to extend stand level models to precision silviculture of *E. globoidea* and *E. bosistoana*

Growth and yield models can be built with data from just permanent sample plots (PSPs), but they are more secure if they are informed by analyses from designed experiments. Designed experiments enable developing precision silvicultural strategies and provide growers confidence to apply site specific management.

Stand density is the extent to which trees occupy a site. Different eucalypt species can differ in their response to stand density and stand density management. Stand density index (SDI) can be used to guide thinning strategies if the maximum stand density index for a species is known on the site where the trees are growing. Therefore, accurate stand density measurement is required to extend the stand level models to precision silviculture models for *E. globoidea* and *E. bosistoana.*

In order to do this a network of silvicultural trials needs to be planted for long term measurement and further model development. These trials would inform on optimizing silviculture through learning about:

- Effects of genotypes in delivering gain
- Effects of spacing on branching
- Implications for pruning for clearwood and value
- Wood durability and heartwood
- Impacts of spacing on yield by log grade
- Financial outcomes of various regimes

Te Uru Rākau New Zealand Forest Service has a Science and Research Plan that includes a woody biomass work stream. This work stream includes planting new short rotation biomass trials of coppicing species. *E. globoidea* and *E. bosistoana* could be included in these trials given the availability of 1st generation XyloGene clonal seed orchard seed of both species.

The trials would have two key objectives:

1. Refine growth and yield models for individual trees, distributions, and at plot-level that incorporate representations of total wood, heartwood, and clearwood following pruning.
2. Provide a sound basis for spacing management of NZDFI species to optimise returns from precision silvicultural regimes on a variety of sites.

Both Nelder circular spacing experiments and block spacing experiments are required.
Nelder experiments require flat sites of around 1 ha in area for testing both species.
Block spacing experiments require much larger areas due to replications needed for a statistically robust experimental design to assess both species. However, the block trials offer significant advantages:

- Replication ensures statistical analyses can accommodate site variation;
- Various pruning and thinning regimes can be compared simultaneously;
- Measurement and analyses can continue until the end of rotation in large plots with buffer surrounds, so that harvest values can be fully assessed.

3.3.4 Case study durable eucalypt growing and harvesting regimes

Authors of this case study assumed that 3,000-3,500ha of *E. globoidea* forests planted in north Marlborough will supply the Kaituna hub and 1,500-2,000ha of *E. bosistoana/E. cladocalyx* planted in south Marlborough will supply the Riverlands hub.

NZDFI has identified two main regimes which growers in these two different sub-regions of Marlborough could adopt. These are a 20-25 year rotation post producing regime that predominates in south Marlborough, and a 28-35 year rotation sawlog/peeler log regime that predominates in north Marlborough. In practice the geographic distribution of the two regimes will be dependent on the landowner's objectives, site suitability, species selection and accessibility for harvesting and transport.

3.3.4.1 North Marlborough – 28-35 year rotation sawlog/peeler production regime

The North Marlborough regime targets the production of class 2 durable sawlogs and veneer logs on north Marlborough's steeper hill country (predominantly pine cut-over), producing 30-70 cm diameter sawlogs and poles with a high percentage of heartwood which can be either peeled for veneer or sawn to produce a range of high-value durable hardwood products including posts and poles, cross-arms, decking, sleepers, outdoor furniture etc. The forestry regime and systems applied are similar to those currently used for radiata pine. Trees planted at 1000-1200 stems per ha; pruned at between 4 and 6 years followed by waste thinning to 400-500 stems per ha at age 9 or 10.

3.3.4.2 South Marlborough – 20-25 year rotation post regime

The South Marlborough regime targets production of class 1 durable roundwood for posts and poles, and possibly veneer for engineered wood products. This regime is suited to easy-to-medium contour land where small-to-medium scale ground-based harvesting is feasible and there is minimal requirement for internal access roads, landings and bridges. Sites need good road access, and to be within economic transport distance of the Riverlands processing hub.

The 20-25 year rotation post regime is a novel regime for New Zealand. A high initial stocking (1600-2000 stems per hectare) is planted and there is no pruning. Production thinning for woody biomass at around 9-10 years may be feasible, otherwise early waste thinning is recommended to remove any poor stems and reduce competition. Following a clear fell harvest, trees will coppice (grow back from the cut stump) and rapidly re-grow but growers will need to prune the coppice back to a single stem to produce another straight single tree. Optimal sites are within economic transport distance to a processing hub or alternatively a portable post-peeler can be used on-site to produce posts for own use or sale to a local market.

The regime is based on growing many trees under a high stocking to a size of between 20-30cm diameter under bark; with long straight stems, minimal taper and a high percentage of heartwood. Rotary peeling of logs could produce veneer for use in engineered wood products; peeler cores for naturally durable posts with diameters between 80 – 200 mm and suitable for vineyards, horticulture, agriculture, and organic enterprises.

3.3.4.3 Regional nursery production and supply required

The annual planting area to establish 3,000-3,500ha of *E. globoidea* forests in north Marlborough is 100 - 120ha. Based on 1,000-1,200 stems per ha, the number of seedlings required annually is around 100,000 - 140,000 seedlings.

The annual planting area to establish 1,500-2,000ha of *E. bosistoana/E. cladocalyx* in south Marlborough is 75 -100ha. Based on 1,600-2,000 stems per ha the number of seedlings required annually is around 110,000 - 200,000 seedlings.

3.3.4.4 Marlborough already has a local specialist nursery, Morgans Road Nursery, that produces high quality eucalypt seedlings from XyloGene seed. This nursery has the capacity to grow all of the seedlings required for these annual planting targets to be achieved. Proseed already hold a substantial quantity of improved seed and expect annual production from their existing seed orchards to increase significantly so there is no shortage to meet the proposed planting targets.Continuous cover regime

While not included within the case study, some sites may provide the opportunity to combine the above two regimes in a continuous cover regime. One or more production thinning operations in a durable eucalypt forest could produce small logs for posts and solid biofuel; the remaining trees then grown on to produce sawlogs. These could be selectively felled and potentially milled on a small scale in the forest to produce posts and /or sawn timber for on-property use or local sale. Coppice regrowth could be managed to develop a multi-age forest.

Growers will need to experiment in developing this regime for their particular circumstances. In some cases (i.e. if the forest is post-1989 and registered for the Emissions Trading Scheme) there could be carbon benefits from maintaining a continuous cover regime (see Section 3.7.4).

3.3.4.5 Whole-tree harvesting

Whole-tree harvesting is another option which could be considered by growers in both north and south Marlborough. Whole-tree harvesting involves being able to efficiently extract and breakdown the whole tree into post and log lengths from the main stem with the upper stem wood, branches and off-cuts of short or misshapen lengths recovered separately for biomass. Whole-tree harvesting could be feasible for solid biofuel and other possible bio-products if the value of these products exceeds harvesting and transport costs, and is most likely to be viable where transport distances are short. NZDFI have identified a potential bio-product that could be produced from *E. bosistoana* foliage as it contains eucalypt essential oils in quantity and quality suitable for commercial extraction[17].

3.3.4.6 Estimating woody biomass yield from whole-tree harvesting

The stand level growth and yield models developed for this case study produce estimates for whole tree harvesting of wood and biomass. It is important to distinguish between dry wood density (mass per unit volume of dry wood), and basic density (dry mass per unit of wet wood). Wood shrinks during drying, and destructive sampling yielded dry wood averages of 909 and 682 kg/m^3 and basic densities of 738 and 517 kg/m^3 for *E. bosistoana* and *E. globoidea* respectively. This partly explains the relationships between wet wood volumes and dry biomass estimates in the model outputs. Nevertheless, stem volumes and biomass do not completely appear to correspond due to differences in fitting for the two models of volume and biomass. They could be brought into agreement by simply employing average basic density to the volume estimates, but this would be less direct that employing two models, and also basic density very likely varies with age. Consequently, the two separate stem volume and stemwood biomass model estimates have been retained in model outputs. As more data is collected over time to refit models, they will very likely become more coherent.

3.3.5 Factors influencing a grower's choice of regime

The success of a future durable eucalypt industry in Marlborough as envisaged in this case study will depend on whether or not landowners establish durable eucalypt forests, ideally at an average rate of 150-200 hectares per year steadily over the next 30 so years to create a minimum 5,000-hectare regional resource. There are many factors influencing an owner's decision to plant, and the growing regime they may choose. These are summarised below.

3.3.5.1 Owners' objectives and resources

Landowners will want a return on their investment into growing durable eucalypts. This could be from timber, carbon, environmental benefits or a combination of these. However, landowners will have different site and environmental conditions and need to ensure it will be feasible to harvest before planting. The scale of forest area they can plant and manage will also vary. Choice of a durable species and regime needs to match these factors.

3.3.5.2 Property soils, climate and land class (LUC)

Site conditions, scale, soils and climate combined with aspect and drainage will also influence the choice of species and regime for any given site.

3.3.5.3 Topography including internal access for regime management and harvest

The topography of a possible forestry site will limit the regime that can be chosen. Flat and easy sites could support any regime including a post and pole regime suited to mechanical ground-based harvesting. On steeper hill country, sawlog production is most likely.

3.3.5.4 Property location including transport options and distance to processing hubs

For this case study the authors assumed that landowners within the regional wood-supply catchments will plant new forests where posts and logs can be easily supplied to one of two local processing hubs.

3.3.5.5 Potential for off-site environmental risks

Landowners need to consider the potential for off-site environmental risks from eucalypt plantations within their own property or on any neighbouring properties.

The two proposed regional wood supply catchments include substantial areas of vineyards. Durable eucalypts contain essential oils in their leaves and these compounds are found in some red Australian

[17] Rajapaksha, C., P. Greaves, C.M.Altaner (2023) "Economic potential for essential oil production from New Zealand-grown *Eucalyptus bosistoana*." Scientific Reports 13, 11/23

wines, where it is described as ‘eucalypt’, ‘camphor’, and ‘minty’ character. The Australian Wine Research Institute conducted research on ‘eucalypt’ character in wine including understanding the source of the character and providing options for winemakers to be able to control it.
Foliage and small stems dropped by eucalypt trees growing close to vineyards are the primary source of the flavour in wine. Grapes harvested from rows greater than 25 or 50 metres from *Eucalyptus* trees gave wines with very low levels of eucalypt oil compared to those grown close to the trees that contained significant amounts of oil. The main research outcome for grape growers is to avoid material other than grapes in picking bins, especially *Eucalyptus* leaves. This dramatically reduces the level of ‘eucalypt’ flavour in red wine. There were negligible effects from this in white wines[18].

Eucalypt (and pine) plantations can also pose a significant hazard in the event of a fire and should be sited at least 30 m away from buildings and infrastructure. If there is a fire within a plantation, the trees will be generally unaffected. However, following fire there is potential for natural regeneration of the wind-borne seed. If this occurs in low productivity farmland or post-harvest forestry areas, this can result in wilding durable eucalypts becoming established. Young wilding seedlings could be hand pulled or controlled by spraying with glyphosate.

3.3.6 Economic feasibility modelling for durable eucalypt forestry

NZDFI has undertaken earlier work on modelling the productivity and economic feasibility of durable eucalypts. This economic analysis was undertaken in the absence of any post or log prices as there is no current market. It is described in our 2019 Strategy document[19]. This modelling compares scenarios for *E. bosistoana* of growing on high and low productivity sites, and short-rotation peeler pole and long-rotation sawlog regimes. The results provided the minimal ‘stumpage’ price required by the grower at harvest using an 8% IRR. A wide range of stumpage prices were calculated that demonstrated high productivity sites would be economical for both regimes. However, while growing posts on low productivity sites is likely to be economical, growing sawlogs was marginal.

Ultimately future returns to growers will depend on several key factors including planting costs and interest rates; growing regime, site productivity and harvest age; transport distances to processing hubs, and product value being driven by market demand and supply. For sites that register in the Emissions Trading Scheme, the NZU (carbon) value could significantly improve grower economics (see the Lawson and Avery case studies, Part 2).

[18] https://www.awri.com.au/wp-content/uploads/eucalyptus_character_in_wine.pdf

[19] Durable eucalypts: A multi-regional opportunity for New Zealand’s drylands. NZDFI Strategy 2020-2030.

3.4 The two proposed regional processing hubs

Two sites for future hardwood processing hubs are proposed for this case study:

- a medium-scale hardwood sawmilling and processing at Kaituna, north of the Wairau River
- a small scale post peeling operation at Riverlands in south Marlborough (Map 3).

Two hubs with two different processing operations will optimize post, log and woody biomass transport distances both for incoming supply and outgoing products to markets.

The possible regional wood flows and supply chain interrelationships between the forests, processing hubs and markets are shown in Fig 5 below.

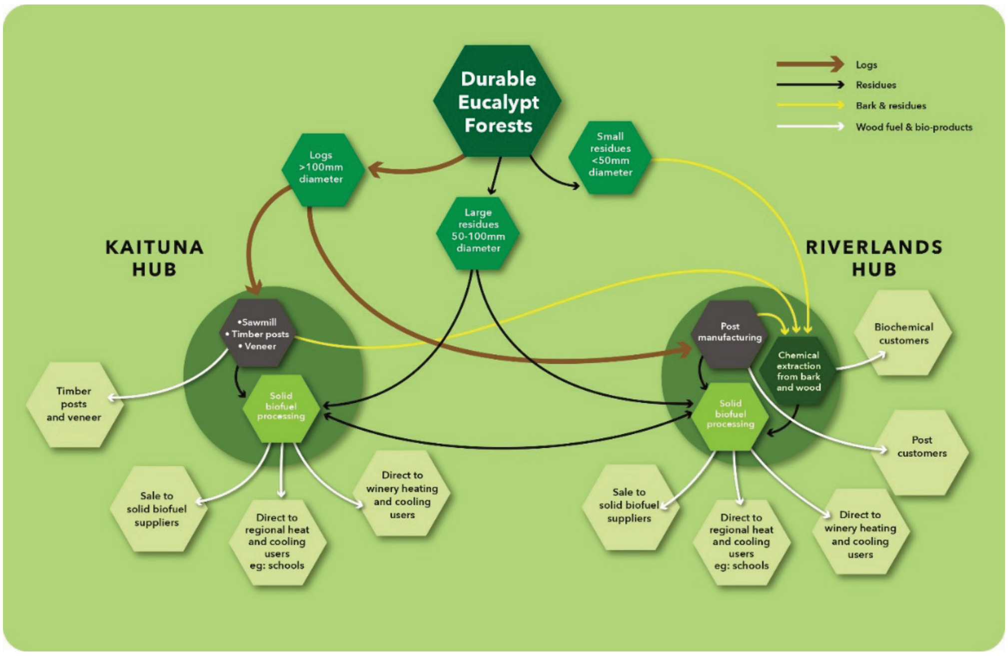


Fig 6: Wood flows possible from forests to processing hubs to markets.

Along with posts and sawlogs, residues will be produced at forest harvest when full stem or whole tree harvesting is feasible. This would recover the upper stem and larger branches (50-100mm diameter) for solid biofuel use. There is also potential for small branches (<50mm diameter) and leaves to be further processed in a biorefinery at the Riverlands hub, where essential oils could be extracted from *E. bosistoana* foliage[20]. Additional residues would be produced during wood processing operations. Solid biofuel produced by both hubs could be sold locally, either directly to end users or to solid biofuel suppliers whose business aggregates residues from a range of sources to supply a regional customer base.

3.4.1 The feasibility of medium-scale regional hardwood sawmilling and processing

Eucalypts are capable of producing hardwood of the highest durability and strength; however, they pose different processing challenges to those of radiata pine. Eucalypt logs can display unpredictable levels of growth-strain, reducing sawing yields and increasing processing costs due to log splitting, warp, and brittle heart. Well-proven cutting strategies are necessary to release the strain during sawing to produce straight lumber.

While some plantation eucalypt is processed in New Zealand, this is largely by small-scale sawmillers and wood processors as there is neither sufficient plantation area nor a sustainable supply for a medium or large-scale regional sawmill and supply chain. Small-scale processing is discussed further under section 3.4.5.

In Australia, native eucalypt forests have been traditionally harvested to supply logs to a wide range of medium and large-scale sawmills. These companies have developed strategies to maximise the

[20] Economic potential of essential oil production from New Zealand-grown Eucalyptus bosistoana | Scientific Reports (nature.com)

recovery of well-seasoned hardwood products that are sold to both domestic and international markets.

An example is Hurford's Hardwood located in far north coast region of NSW. Their supply chain is based on five processing hubs supplied with native eucalypt logs that produce durable hardwood. They deliver product into their global sales and distribution chain that includes an Auckland showroom[21] supported by a warehouse in Tauranga offering '*a full range of quality Cladding, both Engineered and Solid Flooring, Decking, Timber Wall Lining and much more*'.

In order to investigate the potential for a new regional wood supply chain, Hawke's Bay Regional Investment Company Ltd (HBRIC) contracted Scion in 2020 to undertake a study of potential log supply from existing alternative species forests in the region and to assess the feasibility of establishing a small-to-medium scale wood processing plant in Wairoa, northern Hawkes Bay[22]. The study followed an investigation of the potential to plant eroding hill country in the Hawke's Bay Region with a diversity of alternative species[23] including durable eucalypts. This study concluded these are a viable forestry option provided there is a future regional log market for growers.

Scion used a WoodScape model to undertake analysis of a potential small or medium-sized regional hardwood processing hub[24]. Assumptions were that the operations will run two shifts per day, 250 days per year, and 46 % plant utilisation to maximise operation at 8,760 hours per year.

Their modelling assumed a smaller-scale operation requires around 50,000 m^3 of logs per annum and a medium-scale operation requires 80,000 cubic metres of logs per annum. The area of forest required for harvest annually was estimated using a 30-year sawlog regime and assumed merchantable log production of 500 m^3 per hectare (Table 1). The figures in Table 1 are for modelling purposes: in reality mill demand, average yields and therefore the area of forest required could be different.

Table 1: Level of annual planting needed over 30 years to create a catchment forest resource to sustainably supply small and medium hardwood processing operations assuming merchantable log production of 500 cubic metres per ha (WoodScape).

Mill demand m^3 per annum	Required area (ha) of planting/harvest per annum	Years of planting	Total area required ha
50,000 (small)	110	30	3,250
80,000 (medium	160	30	4,800

The supply chain proposed for the smaller-scale hardwood processing operation was further modelled using WoodScape under the assumption that from 2050, a sustainable annual supply of 52,000 m^3 of hardwood logs could be harvested from around 110 hectares of forest to supply the hardwood processing hub (Table 2).

Under this scenario a processing hub of could produce 30,000 m^3 of lumber (rough-sawn timber) with 24,000 m^3 of this further processed into higher-grade product and the other 6,000 m^3 of low-grade lumber sold without further processing.

The higher-grade lumber produced by further processing produce 21,600 m^3 of high-value hardwood products. This supply chain would produce some 13,000 m^3 of 'residuals' or 'residues' such as offcuts, shavings and sawdust (Table 2).

[21] Hurford Hardwood high quality Australian hardwood products
[22] Hall, Peter (2020) Assessment of afforestation a future wood processing opportunity with non-radiata species – Wairoa District. Report produced by Scion for Hawkes Bay Regional Investment Company Ltd.
[23] Harnett M. (2019). Planting eroding hill country in the Hawkes Bay region: right tree right place right purpose. Scion Contract report for the Hawkes Bay Regional Investment Company. Scion PAD No. 17565528.
[24] Jack M., Hall P., Goodison A. and Barry L. (2013). WoodScape Study – Summary Report. Scion contract report to Woodco (Wood Council of New Zealand Inc. Scion SIDNEY output No. 50738.

Table 2: Wood processing model assumptions for a small-scale processing hub which includes a sawmill and a remanufacturing (secondary processing) plant.

Small mill processing hardwoods (eucalypts) – 5-hectare site	
Logs in m^3 per annum	52,000
Lumber out m^3 p.a	30,000
Low value products out m^3 p.a	6,000
Remanufacturing in m^3 p.a	24,000
High value products out m^3 p.a	21,600
Residuals out m^3 p.a	13,000
Log price delivered in $/$m^3$	$195
High value products produced price $/$m^3$	$1,950

Key assumptions used in the WoodScape model were an estimated 'delivered to the sawmill' log price of $195/ m^3, and an average product price of $1,950/ m^3.

Using these values, the model calculated that overall gross domestic product (GDP) contribution to regional economy from planting a minimum of 3,250 hectares of forests over 30 years could create a regional hardwood industry projected to be worth around $82.5 million per annum and deliver an estimated return on capital employed (ROCE) of 25%.

Scion also projected that employment created by a regional hardwood industry based on a small-scale processing operation could include:

- Forest establishment and management: 3-10 full time equivalents (FTEs)
- Forest harvesting - one crew: 9-10 FTEs
- Sawmilling: 54 FTEs
- Remanufacturing: 131 FTEs

Further employment would be created in, for example, transport, administration, and support services.

Scion also identified around five hectares would be required for this operation and that it would have a low environmental footprint. For example, that sawdust and shavings from sawmilling and remanufacturing could be utilised to provide heat for drying kilns. However, the sale of slab wood that makes up the bulk of the 13,000 m^3 of residuals was identified as critical to financial viability. Direct sale as firewood was proposed although this would be limited by the local demand.

Scion undertook a brief analysis using the WoodScape model of including an integrated small-scale pellet mill as part of the processing operations. Wood pellets match the volumetric energy density (GJ/m3) of coal better than wood chip or hog fuel so the major capital expense in replacing a coal boiler is avoided if wood pellets are selected as the principal heat source. Based on the assumption that the sawmill residues were available at zero ($0) cost, the ROCE of the pellet mill was estimated at 12%.

As Scion undertook its Wairoa feasibility study[25] in 2020, these figures will need to be inflation-adjusted. However, this study provided the basis for NZDFI to extend the vision of future regional hardwood industries to other regions, including Marlborough and provided a clear focus for promoting regional planting targets of 5,000 ha over 30 years.

For this Marlborough case study, the scope of Scion's outcomes has been applied but with the addition of a second processing hub to peel posts. Assumptions about rotation lengths, stocking rates and site productivity in terms of total recoverable volumes, and piece sizes in north and south Marlborough are based on NZDFI trial data and growth models. A range is used for many of these indices to reflect likely variations in site productivity, harvest age and owner objectives.

[25] Hall, Peter (2020) Assessment of afforestation a future wood processing opportunity with non-radiata species – Wairoa District. Report produced by Scion for Hawkes Bay Regional Investment Company Ltd.

3.4.2 Hardwood posts – market size and processing feasibility

Across Marlborough's over 31,700 hectares of vineyards, the industry standard is CCA-treated pine end-assemblies (using strainers, stays and blocks) in combination with trellis posts (2.4 m long half, quarter and full round). Over the last twenty years an array of alternative post types has been deployed including posts made from steel and plastic and a combination of these. Also, polyethylene covered untreated pine posts and imported durable hardwood posts have been deployed.

The ALRTIG tree breeding programme identified there was potential to genetically improve heartwood produced by eucalypts that can produce class 1 durable hardwood at age 8-10 years[26]. This outcome provided impetus to NZDFI's research and development programme in Marlborough to substitute CCA-treated posts with naturally durable hardwood posts. At this same time, New Zealand's organic growers had identified the need for an alternative product to CCA-treated wood[27].

More recently, Sustainable Wine NZ has committed to phasing out the use of CCA-treated wood by 2050[28]. While some broken vineyard posts can and are being recycled, ultimately, they become hazardous waste requiring a secure landfill or an environmentally safe wood waste processing facility, of which none has been built in NZ.

In contrast to New Zealand, in the European Union, United States and Australia, use of CCA-treated timber has been heavily restricted for many years[29,30]. While other more benign wood preservatives have been approved by New Zealand standards, they are not used by the New Zealand treatment industry, and, in Europe, there is a general perception that naturally durable timber is a superior, safe and eco-friendly product.

The University of Canterbury School of Forestry has done a significant amount of research on producing posts and veneer from durable eucalypt timber under the Specialty Wood Products Research Partnership (SWP) [31]. This includes research to analyse the treated wood market for agricultural and horticultural uses in New Zealand[32]. CCA-treated pine posts and poles are the dominant product used by these industries. The total volume of CCA-treated wood in use by New Zealand's agricultural and horticultural sectors in 2020 was approximately 6.9 million m^3. In addition, sales were estimated at between approximately 270,000 m^3 to 310,000 m^3 per year.

3.4.2.1 Testing durable eucalypt posts *in situ*

In Marlborough, Vineyard Timbers first identified the potential for naturally durable vineyard posts in 2003. Over a period of five years, the company sourced New Zealand-grown durable eucalypt square sawn posts and sold these to Marlborough vineyard owners. Most of these posts were installed throughout vineyard properties within the lower Wairau Valley to replace broken CCA-treated posts with some used to establish a new vineyard.

In 2017, an in-service assessment of over 1,000 eucalypt posts demonstrated there had been only 0.02% breakage. A further in-ground assessment of 150 posts showed *E. bosistoana* posts had less decay than *E. globoidea* posts after 8-10 years in service. However, at that stage there had been no post failure of either species due to decay[33].

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[26] Bush D & McCarthy K (2009) Scope for genetic improvement of natural durability in low rainfall eucalypts for vine trellis posts. RIRDC Publication No 09/012, ACT, Australia 45 pp

[27] Organics Aotearoa NZ (2010). Over The Fencepost - Alternatives to CCA (Copper Chromium Arsenate) treated wood. New Zealand,

[28] Sustainable Winegrowing New Zealand (2022) *National Greenhouse Gas Emissions and Energy Use Report* https://www.nzwine.com/media/22253/nz-winegrowers-sustainability-report-2022.pdf

[29] Read, D. (2003). Report on Copper, Chromium and Arsenic (CCA) Treated Timber. New Zealand, Environmental Risk Management Authority (ERMA) 68.

30 Altaner C.M. (2022) *Preservative Treated Wood Products in New Zealand*. Cellulose Chemistry and Technology 56(7-8):705-716 DOI:10.35812/CelluloseChemTechnol.2022.56.62

[31] https://nzdfi.org.nz/wp-content/uploads/2021/12/Durable-eucalypts-Tree-Grower-November-2021.pdf

[32] SWP T114 (2021): Analysis of the treated wood market for agricultural and horticultural uses in New Zealand. Boris van Bruchem, David Evison and Clemens Altaner.

[33] SWP T039: (2017) Performance of naturally durable eucalypt posts in Marlborough vineyards. Paul Millen and Clemens Altaner.

3.4.2.2 Small-scale post manufacturing

Manufacturing of round wooden posts is a mature technology, with existing machinery of various capacity and different technical solutions already operating in New Zealand. The suitability of existing machines for processing durable hardwood posts required testing, and this work was done as part of the SWP[34]. Two post-peeling machines were tested, an in-situ 'Morbark' post peeler at Dashwood Timber, Renwick in Marlborough and another smaller Schälprofi 500 mobile unit at an Invercargill operator's yard.

The trial compared the performance of the two machines peeling *E. bosistoana, E. globoidea* and *E. quadrangulata* logs. The machines had no problem with the high-density eucalypt timber but had mixed performance in removing thick fibrous eucalypt bark. Debarking technology for eucalypts is available and the conclusion reached was that some species will need debarking in the forest or at the processing site before post peeling. Videos made of each peeling trial are available on the NZDFI website[35].

3.4.2.3 Comparing durable eucalypt posts with other types of posts

A Scion study completed in 2021 compared the potential for, and costs of, producing durable eucalypt posts with CCA-treated wooden posts, as well as posts made from other materials[36]. Generally, these non-wooden posts have retail prices that are higher than the CCA-treated wooden posts.

Scion estimated the wholesale value for durable eucalypt posts needed to be $890 per m^3 when the costs of growing and processing, including profit margin were included. CCA-treated pine posts and non-wood post retail prices were researched for comparison (Table 3).

Table 3: Retail price per m^3 of wooden posts or equivalent number of non-wooden posts.

Post type	CCA pine	Durable eucalypt	Steel	Concrete	Plastic	Wood / plastic	Wood / concrete
$/m^3	$741	$890	$1,749	$2,029	$1,202	$1,006	$1,470

CCA-treated wooden posts were the lowest price option identified by Scion with the costs (including grower and processor profit margins and retail sales margins) of growing and processing durable eucalypt posts calculated to be 20% higher than CCA-treated posts.

Scion further considered the green-house gas (GHG) footprint of the various types of posts. Posts made of concrete and steel will inevitably have a higher GHG footprint (because of the high energy intensity fossil-fuel-based processes used to manufacture them) than posts made of wood (which are a medium-term store of carbon). Heat in the form of steam could be produced from post peeling and used in a pine post treatment system or sold for biofuel if produced from durable eucalypt post peeling.

The environmental footprint of plastic posts is less clear. While made from a waste stream and reducing the volume of plastic going to landfill, heat is required to process the plastic prior during post manufacture. Plastic posts can be recycled again if damaged whilst in service but the release of microplastics into the environment is unknown. There is likely to be some end-of-life disposal of all posts, regardless of type.

A total life cycle analysis of the production of durable hardwood post was not a focus for this project but this could inform the Marlborough wine industry's sustainability goals.

[34] *SWP T123 (2021)* Feasibility trials – peeling posts from durable eucalypt logs. Daniel Boczniewicz, Paul Millen and Clemens Altaner

[35] https://nzdfi.org.nz/news-and-events/nzdfi-videos/

[36] *SWP T127 (2021)* Techno-economic analysis of posts from specialty wood species and radiata pine. *Peter Hall and Rosie Sargent.*

3.4.3 The feasibility of regional scale veneer processing

Veneer is a thin sheet of wood produced either by slicing or peeling logs. Peeled sheets can then be glued together to produce plywood, and a strong, stable product used in construction called laminated veneer lumber (LVL). While there is no LVL manufacturing plant in Marlborough, Nelson Pine Industries produce LVL at Richmond, near Nelson. This plant was commissioned in 2002 to peel and laminate pine veneer. In combination with its MDF (Medium Density Fibreboard) operation this is a very large-scale regional operation with capacity to process one million cubic metres of logs per annum. Intake includes logs from Marlborough[37].

LVL producers in New Zealand are looking for an alternative fibre supply to radiata. Production of LVL from radiata pine is currently commercially viable: however, preservatives are required to make the radiata products resistant to borer and decay. Such treated products are perceived negatively in some export markets.

More importantly, radiata pine cannot be used to produce the very high stiffness products which are essential in large timber buildings, and the size of timber buildings being built world-wide is increasing dramatically. Super-stiff timber products (16 gigapascals (GPa – a measure of stiffness) and above) cannot be manufactured economically from radiata pine as it does not produce stiff-enough wood.

Radiata pine logs contain a considerable amount of low-stiffness corewood. This restricts the production of structural grade veneers to the outerwood of the stem. The corewood is rejected in large-diameter peeler cores and used for lower value products such as MDF or firewood. The need for outerwood requires large, good-quality logs from older trees and decreases recovery of structural veneer from these logs. Both effects increase fibre cost.

Low-cost spindle-less lathe technology is extensively used in China for peeling non-durable sub-tropical eucalypt species[38]. Australian plywood manufactures have also replaced conventional lathes with spindle-less technology, and there is on-going research into, and promotion of, the use of small diameter eucalypt logs for rotary peeled veneer production[39]. Recovery of dry graded and trimmed veneers is around twice as high as sawn timber for such a resource[40].

NZDFI's eucalypts can produce hardwood exceeding the stiffness of radiata pine, even from young trees. Moreoever, the heartwood will be naturally durable. Therefore, these eucalypts are well-suited to supply wood for structural timber products such as LVL or plywood, achieving two different objectives. First, higher value structural products (16 GPa and above) that require exceptionally stiff veneers could be obtained. Second, the current LVL products (8-13 GPa) being manufactured from radiata pine, could be produced at a lower cost by utilising short rotations and achieving higher veneer yields[41].

3.4.3.1 Testing the feasibility of veneer production from New Zealand-grown durable eucalypts

To assess the potential of NZDFI durable eucalypts as a veneer product, researchers at the University of Canterbury School of Forestry conducted two small trials in collaboration with Nelson Pine Industries. The first of these was in 2016 when *E. globoidea* logs from a 30-year-old Manawatu stand were transported to the Richmond plant for peeling. The conclusions reached from this trial included:

- high quality veneers can be obtained from *E. globoidea*
- veneer quality and yield are highly variable from this unimproved resource: growth strain (when logs or timber split after felling or processing) was a major factor affecting veneer yield
- high conversion and veneer quality was associated with stronger logs.

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[37] Nelson Pine Industries Ltd

[38] Arnold, R.J., Xie, Y.J., Midgley, S.J., Lou, J.Z., & Chen, X.F. (2013). Emergence and rise of eucalypt veneer production in China. *International Forestry Review, 15*(1), 33-47.

[39] McGavin, R.L. (2016). *Analysis of small-log processing to achieve structural veneer from juvenile hardwood plantations*. Retrieved from http://hdl.handle.net/11343/59117

[40] (https://www.fwpa.com.au/forwood-newsletters/1814-tech-enabling-better-land-management-and-extra-revenue-for-private-native-sector.html).

[41] Guo, F., & Altaner, C.M. (2018). Properties of rotary peeled veneer and laminated veneer lumber (LVL) from New Zealand grown *Eucalyptus globoidea*. *New Zealand Journal of Forestry Science, 48*(1), 3. doi: 10.1186/s40490-018-0109-7

The results suggested that the top 25% (lowest growth-strain) of the stems of an unimproved *E. globoidea* resource could be processed into quality veneers with a reasonable yield.

The second trial was peeling 15-year-old trees. This trial demonstrated that rotary peeled veneers of good surface quality can be obtained from 15-year-old *E. bosistoana* and *E. quadrangulata* trees grown in New Zealand. The mechanical properties of the *E. bosistoana* veneers and their radial profiles were comparable to the best species investigated in Australia (*E. cloeziana* or *Corymbia citriodora*) from a similar aged resource and outperforming radiata pine[42].

A desk-top analysis showed that the value of *E. bosistoana* produced under a 10–20-year rotation and utilised for veneer, with peeler cores being sold as ground-durable posts, exceeded growing costs[43]. However, veneer yields were reduced by growth stresses that caused veneers to split and irregular stem form that reduced the amount of peelable veneer. Therefore, low growth strain and straight stem are key selection traits for the *E. bosistoana* breeding programme to produce trees for LVL markets.

The same study showed tree form and wood properties had a larger effect on tree value than product prices. In a case where peeler cores were sold as ground-durable posts, tree value would increase by 50% to 65% depending on size, when average stem properties were improved by one standard deviation. Marketing peeler cores as ground-durable posts or increasing veneer yields with spindle-less lathes were particularly beneficial for smaller diameter logs, raising their value by up to 100%.

3.4.3.2 Peeler post production – an Australian example

Super Plantation Forests is an Australian durable eucalypt grower and processor, and a member of the Durable Eucalypt Forum[44].

This company has installed a post-making operation using a spindle-less lathe, investing around AU$300,000 in total. This covered purchase of a lathe, plus purpose building in-feed and outfeed systems and waste belt. They can produce 250 posts per day. At present trees are production thinned for processing. The peeled veneer is used as mulch in their forests, although other markets will be explored. Ultimately mature trees will also be converted into power poles[45].

3.4.4 Summary: the suitability of durable eucalypts for veneer production

In summary, durable eucalypts have several proven key characteristics that could add value by their use in LVL or plywood:

- High strength and stiffness: durable eucalypts are very stiff, even at young age, adding strength to engineered wood products beyond what can be delivered by radiata pine
- Fibre cost: eucalypts grow fast and due to their higher stiffness at young age, they can be peeled to a narrow peeler core (~2 cm) with low-cost technology such as spindle-less lathes. This allows use of small diameter (i.e. young) logs to produce veneer with adequate/good stiffness
- Natural durability: durable heartwood allows for manufacture of preservative-free durable/insect resistant products.

3.4.5 The option of portable sawmilling and small-scale processing

Portable sawmills or small-scale stationary sawmills provide a low-cost entry into sawmilling and processing alternative species (including eucalypts) grown in farm woodlots and small plantations. The scale of use and production of these mills in New Zealand was investigated under the Specialty Wood Products (SWP) programme in 2020[46]. Industry data was used to estimate commercial sawmilling production by these mills at up to 80,000 m^3 annually of alternative NZ grown timbers. The value of timber produced was estimated at $85.76M using an average green sawn value of $1,072 per m^3.

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[42] SWP-T079 (2019) *Rotary peeling of 15-year-old* E. bosistoana *and* E. quadrangulata. *C Altaner, F Guo, P Millen.*

[43] SWP T101 (2020) *Value of veneer, wood fibre and posts from improved* Eucalyptus bosistoana *trees. Clemens Altaner.*

[44] The Durable Eucalypt Forum https://nzdfi.org.nz/wood-users/the-durable-eucalypt-forum/

[45] SWP File Note (2019) Report on visit to the Durable Eucalypt Forum, Australia. Marco Lausberg.

[46] SWP-T100 (2020) Portable sawmilling of locally grown alternative timber species: A report on the potential for a sustainable small-scale regional industry in Hawke's Bay Region. Report prepared for Hawke's Bay Regional Council and Hawke's Bay Regional Investment Company Paul Millen

Dashwood Timber at Renwick and Rapaura Timber are Marlborough examples of small-scale stationary sawmills and wood processing that saw and process alternative locally grown timbers.

Small-scale contractors could start a mobile vineyard post and/or hardwood production business equipped with a portable sawmill and/or a tractor-mounted post-peeler. They could service small-scale forest growers and/or vineyard owners wanting to manufacture their own posts and other fencing material on-site, with minimal transport and associated emissions. Contractors like this could become established by harvesting some of the earlier trials and small forestry blocks that were planted in the past 20 years as a consequence of NZDFI's work on these species.

3.4.6 Building on Scion's feasibility study

NZDFI's vision for regional hardwood industries has always been market-focused, and in 2021 NZDFI produced the following assessment of market potential (Table 4):

Table 4: Market opportunities for durable hardwood.

Product	Market opportunity	Current market value
Sawn timber	Domestic substitution of CCA treated sawn timber for outdoor use – estimated annual domestic consumption of sawn timber exceeds 400,000m^3 per annum	$280-320 million per annum based on retail value of $700-800 per m^3
Posts and poles	Domestic substitution of CCA treated agricultural/horticultural posts - demand estimated at 300,000m^3 annually	$210-240 million per annum based on retail value of $700-800 per m^3.
Engineered wood	Utilisation as a component of high value and high strength hardwood laminated veneer lumber (LVL) and cross-laminated timber (CLT)	International value of high strength veneer is $400 - 500 per m^3
Hardwood imports	Substitution of high value hardwood imports – over 72,000m^3 lumber, 1,500m^3 sleepers and 5,000 m^3 posts/poles[47].	$112.5 million in 2019 with average value of $1500 per m^3.
Export markets	Significant lumber and log export potential to replace Australian and tropical hardwoods with certified timber.	Annual export value of 100,000m^3 of lumber is $150 million.

New Zealand imports many millions of dollars' worth of hardwood every year, much of which could be substituted by New Zealand-grown timber including durable eucalypts. Logging in Australian native forests is becoming very restricted, with the closure of state-owned eucalypt forests in Victoria and Western Australia reducing national supply by 40%[48]. This offers a significant export opportunity for New Zealand grown durable hardwood products.

Scion's Wairoa feasibility study[49] provided the basis for NZDFI to extend the vision of how planting forests could supply future regional hardwood industries to other regions. In 2021 NZDFI developed a national concept plan[50] for twelve wood supply catchments centred round local processing hubs.

Scion's Wairoa study outcomes provided a clear focus for NZDFI to promote regional planting targets for each wood supply catchment of 5,000 hectares over 30 years. From these forests a sustainable

[47] MPI (2019)
[48] End of an era for native timber harvesting | Latrobe Valley Express
[49] Hall, Peter (2020) Assessment of afforestation a future wood processing opportunity with non-radiata species – Wairoa District. Report produced by Scion for Hawkes Bay Regional Investment Company Ltd.
[50] Our vision - NZ Dryland Forests Innovation (nzdfi.org.nz)

annual supply could then be harvested sufficient to justify investment in a sawmill and hardwood processing hub.

Therefore, in this Marlborough case study, the scope of Scion's outcomes has been applied but with the addition of a processing hub to peel posts. For the purposes of this case study assumptions about rotation lengths, stocking rates and site productivity in terms of total recoverable volumes, and piece sizes in north and south Marlborough are based on NZDFI trial data and growth models. A range is used for many of these indices to reflect likely variations in site-productivity, harvest age and owner objectives.

3.4.7 Kaituna sawmill and hardwood processing hub

The Kaituna hub location has been selected for the case study as this is site is already a strategic location for Marlborough's pine industry being alongside the site of the One-Forty-One sawmill and is assumed to be principally supplied from *E. globoidea* forests growing in north Marlborough.

There is adequate flat land adjoining the existing mill which would be suitable for extending its use to durable hardwood sawmilling and processing. At least five hectares is estimated as the area required for sawmill and remanufacturing operation processing around 50,000 m^3 per annum, supported by a log storage area, an area for air-drying hardwood lumber and possibly a pellet mill.

The site has good electricity and water supply, road access and proximity to potential skilled employees in Blenheim. The main constraint on current operations is noise, as the Kaituna mill is near residential areas. Also, as the spare land is not zoned for this use then either a resource consent application or a re-zoning would be required from the Marlborough District Council. This is more fully discussed in section 3.7.3. It is assumed that consenting of the proposed activities is feasible.

Product supply

The Kaituna hub would supply the following:

- Sawn timber for solid wood products
- Wood fuel products
- Veneer (if cost-effective)

The following assumptions are made about the forestry regime:

- *E. globoidea* 28 - 35 year rotation. Final crop of 400-500 stems per hectare grown to 30-70 cm diameter at breast height (DBH).
- Total recoverable sawlog volume average 500-600 m^3/ ha.
- Harvest required of around 100–110 ha/year to generate 52,000 m^3 log supply for the mill Total forest area required approx. 3,000–3,500 ha.
- Delivered log price of $195 per m^3 and product price of $1950 per m^3 used in WoodScape. (This compares with domestic log prices in 2024 for pruned radiata of $185-190 per m^3 and the value of NZ exported sawn pine timber is around $700 per m^3)[51].

For this case study assumptions for the wood processing operations and outputs at the Kaituna hub are the same as those applied in the Wairoa case study (section 3.4.1 Table 2).

3.4.8 Riverlands hub - post production

The Riverlands hub has been identified for this case study as this is already an extensive industrial location with many manufacturing and processing companies/industries and a rail head for the main trunk line.

This hub is assumed to be supplied with *E. bosistoana, E. cladocalyx* and *E. globoidea* logs (and additional forest harvest residues) grown in south Marlborough to produce peeled vineyard posts.

[51] Canopy website Dec-2022-quarterly-trade-export.xlsx (live.com)

Product supply
The Riverlands hub could supply the following:

- Posts and poles
- Solid biofuel products – chip; pellets
- Possibly veneer
- Essential oils from *E. bosistoana* foliage

The following assumptions are made about the forestry regime:

- Based on 20–25 year rotation for low productivity dry south Marlborough forests sites. 550-650 stems per hectare grown to 20-30 cm DBH
- Assume total recoverable log volume 100 - 200 m^{3}/ ha.
- Harvest of around 100 ha/year could deliver 15,000m^{3} / year to mill
- Total forest area required approx.1500 - 2,000 ha matched with ground-based harvesting systems

The following assumptions are made about the post processing operation:

- Target annual production – 500,000 posts (50% of current annual demand)
- 45 posts per m^{3} cubic metre – total peeled post volume approximately 11,000 m^{3}
- Sustainable supply required - 15,000 m^{3} unpeeled posts (based on 75% conversion)
- Residue production (chip or veneer) - 4,000 m^{3}
- Retail value of posts between $700 - 800/$m^{3}$
- 11,000m^{3} of posts could have an estimated sale value of around $7.7 – $8.8 million/yr.

NZDFI estimates that the total Marlborough regional demand for vineyard posts totals around 1,000,000 posts annually – equivalent to around 22,200m^{3} of posts, with a market value of $15.5 - $17.6 million/yr. The Kaituna hub could supply additional posts if durable eucalypt posts come to dominate the local market and there is market demand from other regions.

3.4.9 Sawmill and post peeling residues – production and potential value

The production and sale of residues by both proposed Marlborough processing hubs will produce significant volumes of residues (i.e. post peeler chips or sawmill slabwood) that can become separate supply chains. The opportunities and potential value of these product streams is discussed in detail in Section 3.5 below.

3.5 The potential to utilise forest harvesting and wood processing residues for solid biofuel in Marlborough

On the basis that 5,000 ha of sustainably managed durable eucalypt forest are established over 30 years to supply two wood processing hubs, both whole-tree harvesting operations and wood processing operations will generate substantial volumes of residues. An important part of this case study is to assess the market opportunities and explore the viability of utilising these residues as solid biofuel or bioproducts.

Potential solid biofuel and possible bioproduct supply chain are shown in Fig 6.

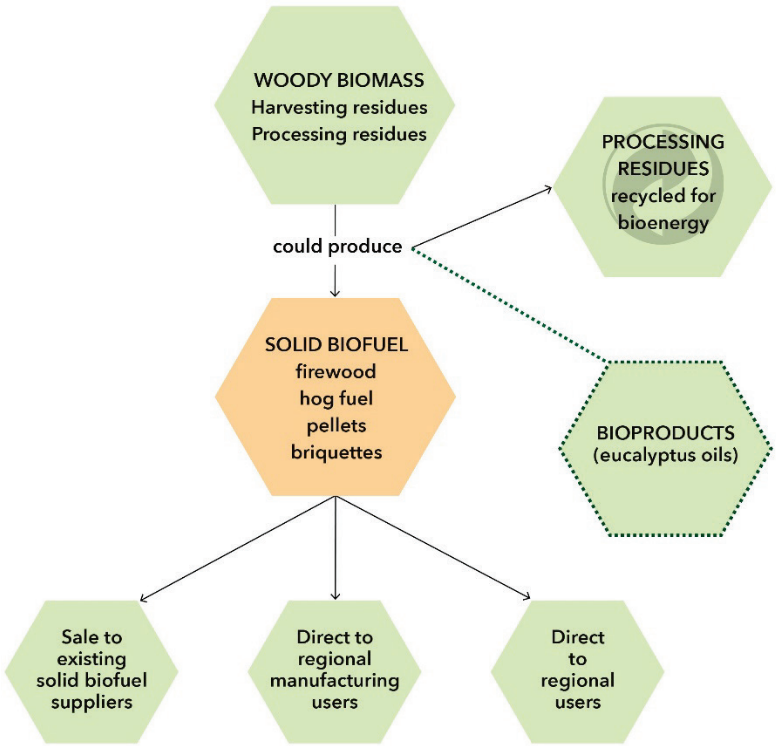


Fig 7: Potential solid biofuel and other bio-products supply chains.

Woody biomass and solid biofuel terminology

The terminology used to describe all the woody biomass derived from a whole tree for solid biofuel use is wide-ranging, the terms used in the context of this report are summarised below:

Woody biomass – the above ground biomass (AGB) of a tree including stem and branches.

Solid biofuel - any product, derived from woody biomass, that can be incinerated to produce **bioenergy. Solid biofuel** is a product (often a 'by-product' or 'residual product') of harvesting and processing trees.

Solid biofuel includes:

- **harvest residues** – log offcuts, mis-shapen reject sawlogs logs; upper stem small logs; large branches and may include small branches and foliage
- **sawmill residues** – slabwood and other off-cuts, shavings, sawdust and bark
- **post-peeling residues** – post offcuts, peelings and chips
- **firewood** – cut to length and split
- **hog wood** – produced by crushing woody biomass for use as solid biofuel
- **pellets and briquettes** (where products are further processed by drying and compressing).

Bioproducts – essential oils and other biochemicals.

The following section summarises current main energy markets and decarbonisation initiatives in Marlborough.

3.5.1 The Regional Energy Transition Accelerator Report for Nelson, Marlborough and Tasman

In November 2023, the Energy Efficiency and Conservation agency (EECA) released a Phase One report as part of the Regional Energy Transition Accelerator programme (RETA)[52], which aims to 'create a pathway through energy transition' from fossil fuels to 'clean and clever' energy.

[52] Energy Efficiency and Conservation Authority (November 2023): Regional Energy Transition Accelerator (RETA): Nelson, Marlborough, Taman Phase One Report

EECA's work on Regional Energy Transition was prompted by the then government's 2022 Emissions Reduction Plan. The Plan has recommendations for policies and programmes necessary for New Zealand to achieve its greenhouse gas emission reduction targets. This provided a strong incentive for heat users to transition from fossil fuels to bioenergy.

Further, a National Policy Statement (NPS) and National Environmental Standard (NES) for Greenhouse Gas (GHG) Emissions from Industrial Process Heat[53], came into force in July 2023. Councils are now required to factor in emissions produced by industrial process heat when assessing air discharge resource consent applications. The regulations provide a nationally consistent framework for reducing greenhouse gas emissions from industrial process heat by:

- *prohibiting discharges of greenhouse gases from new low to medium temperature coal boilers immediately and from existing coal boilers after 2037 (after this date no further consents can be issued)*
- *requiring resource consent to be held for new and existing fossil fuel boilers that emit 500 tonnes and above of CO_2-e per year, per site*
- *requiring resource consent applicants to prepare and implement greenhouse gas emission plans and set out actions to reduce emissions.*

EECA's Nelson/Marlborough/Tasman RETA report was timely in relation to this Marlborough case study because substantial data on regional energy use, current and future potential use of biofuel for energy generation, and the wood and residue flows of the region's existing forestry and wood processing industries were collated for this report. Therefore, this RETA report has been drawn on to support the following section on solid biofuel production and its potential uses in the Marlborough region.

The RETA report is referred to herewith as *'EECA NMT 2023'.*

3.5.2 Transitioning from fossil fuels to solid biofuels in Marlborough

3.5.2.1 Existing use of fossil fuels for heating

The Marlborough area has an extensive current and future energy demand to produce heat for industrial, commercial and residential applications. This is currently met from biomass, electricity and fossil fuels (coal, LPG and diesel). Fig 7 shows the types of fossil fuels used in the Marlborough/Tasman region to produce stationary heat which users seek to replace by renewable energy. The proportion of each fuel type used is likely to be reflected in Marlborough alone (coal – 71%, diesel 20%, LPG 9%).

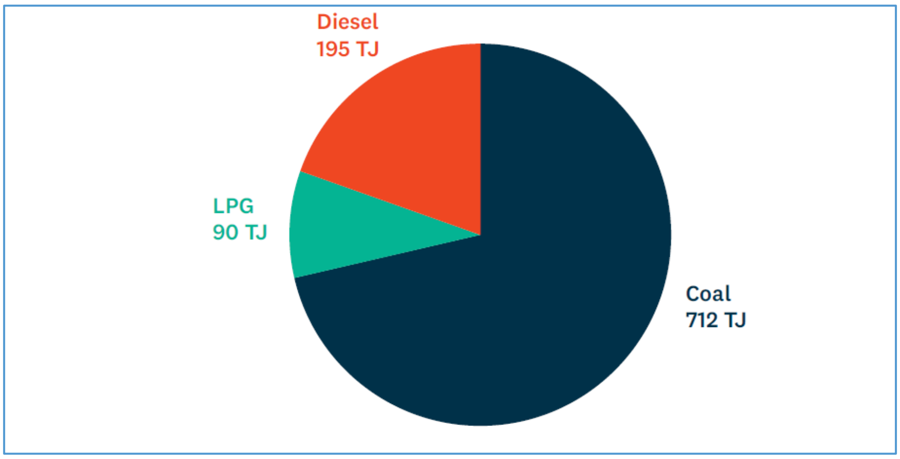


Fig 8: Percentages of fossil fuel used in stationary heat in the Marlborough/Tasman region (Source: EECA NMT 2023)

As heat users currently using fossil fuels decarbonise their heating requirements, they will transition to electricity or biofuels as their renewable energy options.

[53] TNSB98 - Calculating emissions produced by industrial process heat

Hydrogen is a possible replacement fuel but that is likely to be very expensive and requires extensive new infrastructure for production and distribution, so is not currently being considered except for in very specific heat applications. Liquid biofuels could be sourced from outside the region, but they are not readily available and their scope was outside *EECA NMT 2023*.

3.5.2.2 Existing use of solid biofuels for heating

The Marlborough region has several schools, public facilities, accommodation and food processing facilities who may already use solid biofuel fuel, and there are other institutions and small industries that could readily convert from fossil fuels to biofuel for heating. Unfortunately, no data could be obtained to substantiate which of these are already solid biofuel users or to estimate the overall total solid biofuel use in the Marlborough region. However, there are a number of local solid biofuel suppliers with their own customer base (see Table 6).

3.5.2.3 Transitioning from fossil fuels to solid biofuels for heating in the Marlborough region

Current heat users may transition away from fossil fuels by investment in refitting existing coal boilers to use solid biofuel, or investment in new electric or biofuel heating equipment. Each heat users' decision making will depend on a range of considerations including the future of their business, the state of existing equipment, future demand for heat, the future availability and cost of solid biofuels, Government regulations, customer requirements, and opportunities for reducing emissions.

EECA studies nationwide conclude that compared to the electricity alternative, and provided that adequate wood biomass is available, solid biofuel produced from forest harvest and wood processing residues is the renewable fuel of choice for industrial heat users transitioning from fossil fuels.

The EECA NMT 2023 report indicates that at expected future carbon prices, some 85% of emissions reductions from projects identified in the Marlborough/Tasman region are economic by 2037.This is considered representative of the Marlborough region.

The electricity alternative - heat pump technology - can be economically viable for small heating loads but generally heating produced from biomass is significantly cheaper than using electricity. This gap is forecast to grow as the future cost of electricity increases faster than the future cost of solid biofuel[54].

The future cost of electricity will increase because of the need to build many more power stations and install significant upgrades for electricity distribution. The future cost of solid biofuel is likely to remain closer to current costs because there is no need for substantive capital expenditure. Increased use of woody biomass to supply a greater volume of solid biofuel requires only investment in land for storage, additional chippers, biomass driers, and transport.

An important driver for food growers and processors transitioning away from fossil fuels to biofuels is consumer demand for environmentally friendly products. The origin and the supply chain must meet high standards and certification. Using solid biofuel for heating meets those requirements provided the woody biomass has been sourced from sustainable forestry[55].

3.5.2.4 Marlborough's largest energy users

EECA NMT 2023 identified 38 dairy, meat, industrial and commercial heat users in the Marlborough/Tasman region that have fossil-fueled process heat equipment larger than 500kW or are sites for which EECA has detailed information about their decarbonisation pathway.

Of these large energy users, thirteen are in Marlborough (Table 5). Together, these sites consume 141 TJ of process heat per annum energy, primarily in the form of coal, and currently produce an estimated 11.9kt per annum of carbon dioxide equivalent (CO_2e) emissions[56].

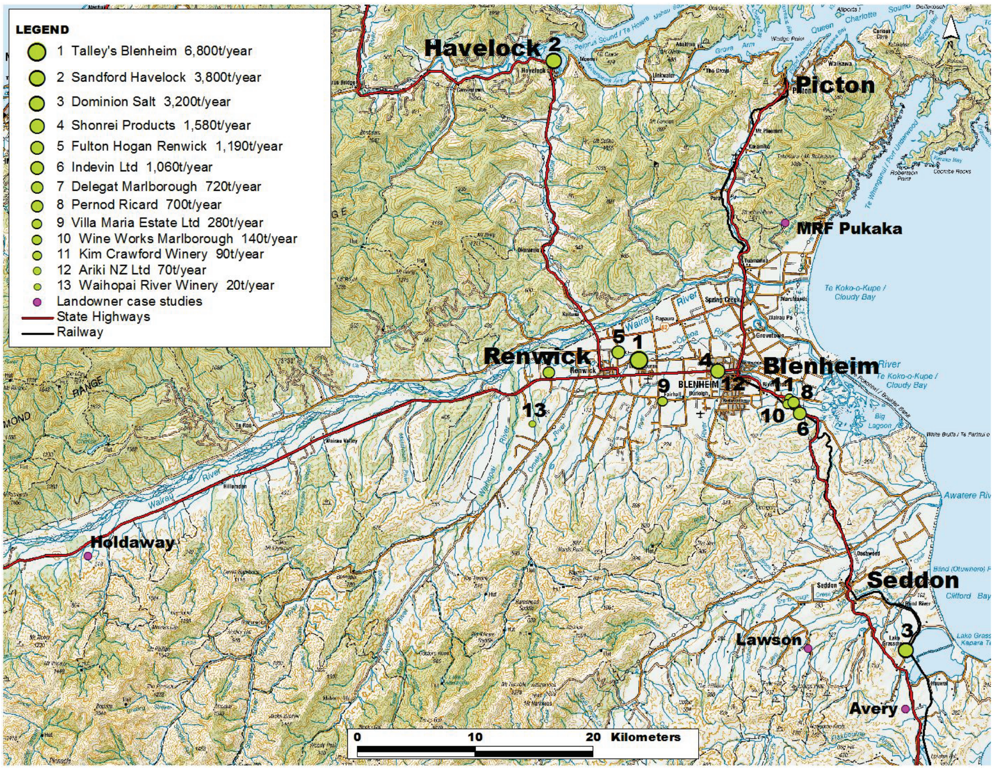
[54] https://www.usewoodfuel.org.nz/resource/tnsb75-future-costs-of-fuel

[55] https://www.usewoodfuel.org.nz/resource/tnsb23-sustainability-of-biomass-fuels

[56] Measuring emissions: a guide for organisations. Ministry for the Environment 2023

Table 5: Marlborough region sites with fuel switching requirements.

Site name	Industry	Transitioning project status	Current energy demand Terrajoules/yr	Tonnes biofuel/year required upon switching
Talleys Blenheim	Pet food & rendering	Confirmed	48.85	6800
Dominion Salt Lake Grassmere	Salt manufacturing	Unconfirmed	23.01	3200
Sanford Havelock	Pet food & rendering	Unconfirmed	27.27	3800
Shonrei Products	High-temperature manufacturing	Unconfirmed	11.38	1580
Fulton Hogan Renwick	High-temperature manufacturing	Unconfirmed	8.54	1190
Indevin Ltd Winery	Winery	Unconfirmed	7.58	1060
Delegat Marlborough Winery	Winery	*Unconfirmed*	5.16	720
Pernod Ricard Winery	Winery	Unconfirmed	5.03	700
Villa Maria Estate Ltd Blenheim	Winery	Unconfirmed	1.99	280
WineWorks Marlborough	Wine bottling	Unconfirmed	1.03	140
Kim Crawford Winery	Winery	Unconfirmed	0.63	90
Ariki New Zealand Ltd	High-temperature manufacturing	Unconfirmed	0.53	70
Waihopai River Winery	Winery	Unconfirmed	0.16	20
TOTAL			**141.16**	**19,650**



Map 4: Marlborough fuel-switching sites (EECA NMT 2023).

3.5.3 Marlborough's current and future regional woody biomass demand and supply

Marlborough's existing plantation forests already generate a local woody biomass supply chain to produce solid biofuel. This has recently extended to the recovery of harvest residues by One-Forty-One based on securing economically viable contracts to sell this woody biomass to solid biofuel companies. Their operation has demonstrated the immediate potential for substantial increase in recovery of pine forest harvest residues for use as solid biofuel across the region.

In addition, the establishment 5,000 ha of eucalypt forest supplying two durable hardwood supply chains has potential to further contribute to regional bioenergy supply.

3.5.4 Current sources of woody biomass for solid biofuel

The Marlborough/ region has approximately 79,000 ha of exotic forests[57]. Radiata pine dominates being 97% of the regional forest resource with Douglas fir, cypresses, eucalypts and other hardwood species making up the balance.

Harvest residues are produced during harvesting and could be for solid biofuel. Data on the availability of harvest residues are split into 'roadside' (skid site, roadside and easily accessible residues), and 'cutover' (residues from stems and branches left in the forest and not as easy to access).

Harvest residue volumes are determined as a proportion of total recoverable volume based on the average of estimates from harvesting studies. Scion[58] has estimated that the Marlborough region currently has the potential to produce 118,000 – 99,000 m^3 of harvest residues which could produce 812 – 682 TJ of energy per year.

The EECA NMT 2023 report identified that in the Marlborough/Tasman region only 6% of harvest residues are currently being recovered for use as solid biofuel. No cutover residues are currently being recovered. The issues faced with residue recovery include:

- accessibility in steep terrain can be difficult, making extraction of cutover residues costly so that recovery is uneconomic
- some roadside residues are not recovered due to the high transport costs to a local market.

3.5.4.1 Marlborough's largest woody biomass producer – OneFortyOne forests

One-Forty-One is the largest plantation owner in Marlborough with around 80,000 hectares of forests across Marlborough and Nelson regions and a harvest of 1.2 million m^3 annually. They have plans to utilise up to 75,000 m^3 of additional biomass across both regions over the next five years for sale to solid biofuel processors.

One-Forty-One forests supply their own Kaituna sawmill which produces 55,000 m^3 of timber each year. All of their wood processing residues (sawdust, bark, woodchip, shavings and post peelings) are either utilised within the sawmill or are sold as a solid biofuel.

Residues are supplied as chip for landscape mulch and to solid biofuel users in Christchurch and Nelson[59]. Some large users located in Marlborough and Nelson are covered horticulture growers, which is a sector with significant potential demand for solid biofuel.

3.5.5 Solid biofuel delivered supply cost

There is no publicly available information on the cost of solid biofuel delivered to end use customers as many variables influence a sale price.

The sale price of solid biofuel needs to include the woody biomass cost paid to the forest grower, the cost of recovery and transport from forest to processing hub. Further storage and processing costs to meet fuel specifications, and delivery costs to the customer need to be met[60].

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[57] 1 Land Cover Database (LCDB5) – 2018
[58] https://www.usewoodfuel.org.nz/documents/resource/Woody-biomass-residues-and-resources-2021-Feb2022_V5.pdf
[59] https://onefortyone.com/news/harnessing-forestry-waste-can-drive-down-new-zealands-coal-dependency
[60] EECA identified that to produce 0.00718 TJ of heat requires on average 1 tonne of biomass fuel (7.184 MJ/kg), and that a cubic metre of biomass residues weighs 1000kg.

Delivered solid biofuel cost data derived for the EECA NMT 2023 for the whole Nelson/Marlborough region is available (Fig 8). This shows a breakdown in the delivered cost of processor and harvesting residues against the cost of lower value pulp and export log grades, and the proportion of the total costs for the transport of woody biomass residues. Modelling undertaken for the EECA NMT 2023 study is based on a scenario that all these residues would be transported to a single solid biofuel processing hub based in Wakefield, Nelson. If there were a regional solid biofuel processing hub in the Marlborough region, then this could halve the transport cost.

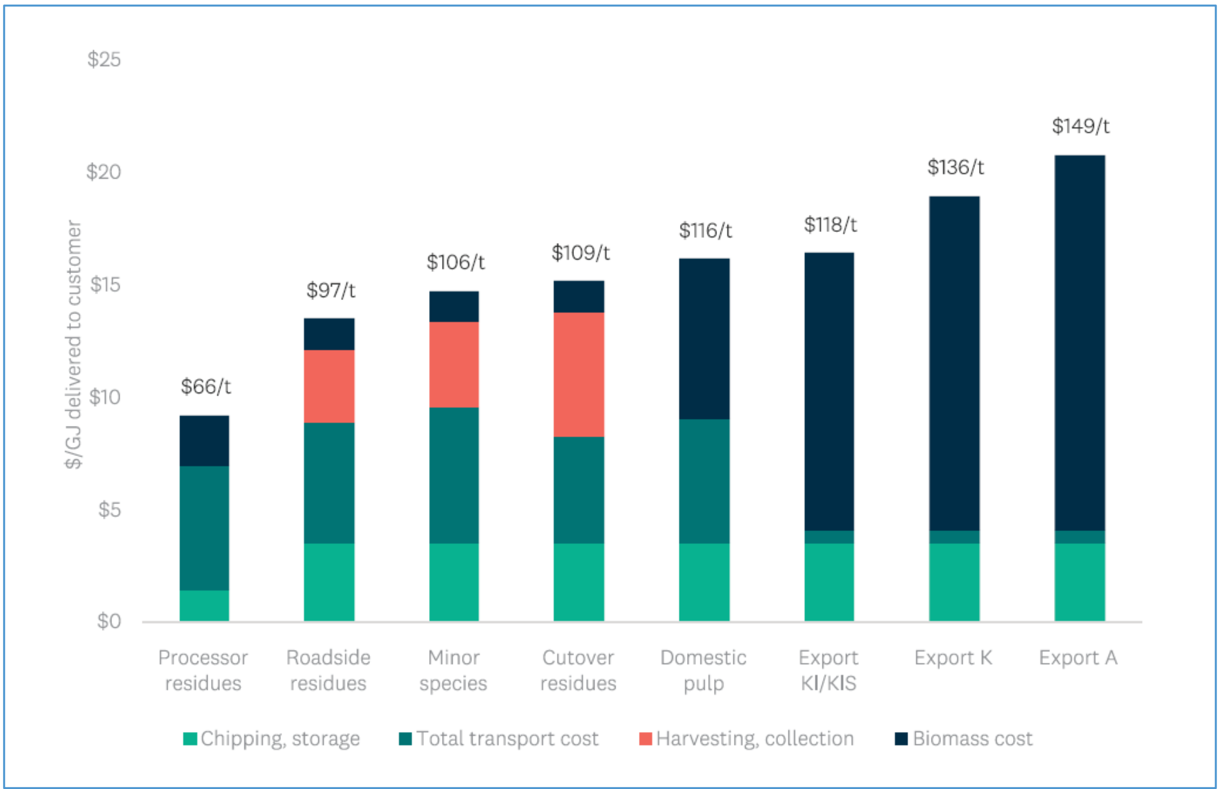

Fig 9: Representative delivered biomass fuel cost from a range of sources (Source: EECA NMT 2023).

3.5.5.1 Supply chains for solid biofuel in Marlborough

Woody biomass residues can be sold under long-term contracts to an accredited Marlborough solid biofuel supplier. Alternatively, some growers may supply residues directly to their own winery, or other businesses with a demand for heat.

Partnering with an experienced solid biofuel suppliers would avoid the need for extensive capital equipment to turn the woody biomass into solid biofuel. Also, the suppliers reduce their market risk as the aggregators hold the contracts with end-users.

Solid biofuel for heating can be supplied from both wood processing and harvest residues. Wood processing residues are a preferred source of solid biofuel compared to harvest residues as they are more homogenous and often have a lower moisture content, i.e. more energy per unit mass. Wood processing residues can be processed by densifying them further into pellet or briquette forms (as is currently done by Azwood in Nelson).

Harvest residues from Marlborough forests are already supplied as solid biofuel to heat plant owners within the region. In addition, demand for solid biofuel from outside the region, particularly by Christchurch users or by the wood pellet production facility at Nelson, has resulted in harvest residues being sourced from Marlborough forests. Solid biofuel is often transported long distances by backloading on otherwise empty trucks.

Solid biofuel suppliers did not divulge the sources of their woody biomass – these suppliers are aggregators of woody biomass from a number of sources. The sources change regularly as they secure woody biomass from multiple forestry harvesting operations to supply their customer base.

There are accredited solid biofuel suppliers working in the market to supply large contracts as well as small suppliers – e.g. agricultural or similar contractors. Many of the small suppliers operate locally and are generally unknown outside their locality. Customers may prefer to purchase from larger accredited suppliers as accreditation provides some guarantee of quality.

Table 6: Solid biofuel suppliers in the Marlborough region

Supplier	Wood fuel type
Heagney Bros Ltd	Firewood
Azwood	Wood pellets, chip fuel, hog fuel
Canterbury Wood Chip Supplies	Chip fuel, hog fuel
The Firewood Company	Firewood
Dashwood Timber & Firewood	Firewood
Centaland	Firewood
Phoenix Firewood	Firewood
Buyright Firewood	Firewood

In addition, to the solid biofuel suppliers listed in Table 6, a number of sawmills and wood processors in the region have processing residues available and may contract to supply these as solid biofuel to heat plant owners. As the solid biofuel market has been expanding a number of the firewood suppliers have been expanding into supplying chip and hog fuel. Some sawmills in other regions have been expanding to produce briquette or pellet fuel.

3.5.6 Other markets for woody biomass in the Marlborough region

3.5.6.1 Market for cooling from solid biofuels

Refrigeration is typically the largest consumer of electricity in the winery, accounting for 50%–70% of total electricity usage. Most wineries require their chiller to be 1-10 °C and 7-15 °C for wine vessels. Electricity costs will inevitably rise with time so consideration of bioenergy for cooling is of emerging interest. However, the use of bio-fueled cooling technology in New Zealand is underdeveloped.

3.5.6.2 Market for liquid biofuels

The region has a significant potential demand for liquid biofuels to replace fossil fuels for both the forestry and viticultural sectors along with other rural based industries; construction and heavy transport (road, marine, rail and aviation). Renewable diesel is an ideal drop-in fuel to replace fossil fuels in heavy transport but is currently not available in New Zealand. Biodiesel from vegetable and animal oils is available from Christchurch but only in small volumes. This case study does not address the regional supply of liquid biofuels.

3.5.6.3 Market for electricity from solid biofuel

The region has a significant demand for electricity with Marlborough Lines intending to expand local solar electricity production. A simple cycle gas turbine using gaseous biofuel in a generator could be used to smooth generation from fluctuating solar production. There is turbine technology developed in other countries using solid biomass for generating electricity, however, an assessment of this is outside the scope of this study.

3.5.6.4 The regional mulch and compost market

Mulch and compost are used by the viticulture and horticulture sectors. Landscape mulch is also used for road embankment and general earthworks protection. Low grade small residues are suitable for making mulch and compost: Forestry companies such as One-Forty-One aim to harvest residues less than 50 mm diameter to recover close to 100% of the woody biomass from their forests.

It could be feasible for all harvest residues including bark to be recovered to process with grape marc and produce nutrient loaded compost. A future investigation of this could be undertaken.

3.5.7 Projections for growth in regional demand for solid biofuel for heating and cooling

Table 5 provides an indication of the existing possible demand for solid biofuel for Marlborough's largest energy users. If all 13 existing fossil fuel heat users in the region transition to solid biofuel this could require supply of 19,650 tonnes per annum. This would be additional to the solid biofuel already being supplied to heat users in the Marlborough region.

Viticulture in the Marlborough region has continued to expand to over 31,000 hectares. Marlborough's wine processing sector is expected to expand and with it the demand for bioenergy. The region's wine sector currently uses energy for heating, cooling, processing and transport. There are six wineries and one bottling plant identified in Table 6: it is assumed for this case study that all of these would at some stage before 2037 commence use of solid biofuel to replace existing electricity or fossil fuel equipment.

Demand for solid biofuel could increase if covered horticulture in the region expands. Covered horticulture requires heating capability which is currently often provided by fossil fuels. Heating with solid biofuel is generally provided by small modular equipment and could utilise locally sourced specific graded solid biofuel.

There is a regional opportunity to increase both supply and demand for solid biofuel. Supply could increase by the recovery of harvest residues and if more logs were processed in Marlborough. The establishment of a durable hardwood supply chain with two regional hubs would also produce additional woody biomass for solid biofuel that could meet future growth in demand for heat throughout the region.

3.5.8 Projected harvest residue flows

The additional volumes of harvest residues that could be produced from the proposed 5,000 ha of durable eucalypts forests have been estimated based on the tree models developed through work phase of this project[61, 62].

Assumptions made to estimate harvest residue biomass for this case study are:

- 3,000-3,500 ha of *E. globoidea* forests will supply the Kaituna hub and 1,500-2,000 ha of *E. bosistoana/E. cladocalyx* planted in the south Marlborough area will supply the Riverlands hub.
- A sustainable supply of posts, logs and harvest residues is harvested annually for processing from across these regional forests.
- Following harvesting 85% of the main stem (>100mm diameter) is recovered for posts and sawlogs; the remaining 15% of the stem (small end) and the branches are suitable for solid biofuel.
- 65% of the branch biomass is recovered for solid biofuel which is the large branches (50-100 mm diameter and length greater than 500 mm). The remaining 40% of small branches under 50mm and all of the foliage is not recovered.

Under these assumptions the harvest of woody biomass for solid biofuel from 28 - 35 year *E. globoidea* in north Marlborough is estimated at 50-100 tonnes/ha. Using an average recovery of 75 tonne/ha and an annual harvest of 110 ha produces a total estimate of 8,250 tonnes of woody biomass annual production for solid biofuel. This estimate is assumed for the case study.

In the case of 20 - 25 year *E. bosistoana* and *E. cladocalyx* in south Marlborough the harvest of woody biomass is estimated at 30-60 tonnes/ha. Using an average recovery of 45 tonnes/ha and an average annual harvest of 100 ha produces a total estimate of 4,500 tonnes of woody biomass annual production for solid biofuel. This estimate is assumed for the case study.

[61] *Individual tree biomass sampling of durable eucalypts (April 2024)*: Report submitted to MPI as part of this SLMACC project.
[62] *Individual tree biomass estimation of durable eucalypts using LiDAR (November 2023)* Report submitted to MPI as part of this SLMACC project.

Some forests with easy topography and good access could production-thin to harvest posts and woody biomass but no assumption has been included for the case study.

3.5.8.1 Logistics of whole tree harvest residue collection

For the case study, whole tree harvest is assumed possible at 100% of the annual forest harvested. However, this may not be feasible at all sites.

In reality, future whole tee harvest operations will be dependent on forest location; access for harvest and storage; transport cost and woody biomass market value. Whole tree harvesting requires having sufficient access for extraction of the entire tree following felling and efficiently cutting to length and stockpiling logs and posts ready for transport from the site. Sufficient area is required for harvest residues to be recovered and separately stored on the skid site ready for pick up. Alternatively, mobile chippers could chip the residues for direct transport to the Kaituna hub for processing into pellets.

3.5.8.2 The economics of harvesting residues

The economic value of harvest residues to the forest grower will depend on sorting and transport costs, and regional market demand for hardwood solid biofuel. Generally, harvest residues are a by-product of the harvest of logs and posts and growers so that growers only need a margin over the costs for separating and storing residues on site.

Transport of logs, posts and biomass is expensive and will continue to be so (see Fig 8, Section 3.5.5). Therefore, the concept of two possible processing hubs with two overlapping wood supply catchments is proposed to encourage planting forests within a 40km radius of each hub.

3.5.9 Projected wood processing residue production

The case study is based on two future supply chains producing posts, durable hardwood products, and possibly veneer, for regional domestic and export markets. Residues generated during processing operations have potential value in a range of solid biofuel and bioproducts markets (section 3.5.3.). However, the bulk of these residues are wet wood that needs to be dried and processed for use as solid biofuel. Therefore, the wet wood volume estimates for processing residues need to be converted to dry biomass estimates. For the case study, the conversion rates for basic density assessed from the results of destructive sampling have been applied i.e. 738 kg/m^3 for *E. bosistoana* and 517 kg/m^3 for *E. globoidea.* The basic density of *E. cladoclayx* is similar to *E. bosistoana.*

The following assumptions are made about annual residue production if both the Kaituna and Riverlands hubs are operating;

- 13,000 m^3 of *E. globoidea* slabwood and offcuts produced at the Kaituna sawmill convert to around 6,700 tonnes of solid biofuel as firewood or pellets. (Sawdust and planner shavings are densified and used to fuel on-site kilns to dry lumber.)
- 4,000 m^3 of *E. bosistoana/E.cladocalyx* post peelings produced at the Riverlands hub are processed using a hammermill convert to almost 3,000 tonnes of solid biofuel.
- Bark is either removed at harvest and left in the forest or it is removed at the processing hub for another use that is outside the scope of this case study.

3.5.10 Aggregated annual woody biomass residues supply from harvesting and wood processing

By 2055, the combined north and south Marlborough supply chains could produce a total of 22,450 tonnes of solid biofuel per year from residues as shown in Table 8. This would be sufficient to supply the 19,650 tonnes of solid biofuel required by the 13 larger regional companies identified in EECA NMT 2023 that need to switch away from fossil fuel use (Table 5).

Table 7: Aggregated annual woody biomass residues that could be supplied from the 5,000 ha forest estate.

Woody biomass source	North Marlborough whole tree harvest	South Marlborough whole tree harvest	Kaituna hub	Riverlands hub	Total supply chain
Tonnes per annum	8,250	4,500	6,700	3,000	22,450

There are no specific prices available for the cost of producing and delivering eucalypt woody biomass. This varies significantly based on the source location relative to the solid biofuel processor. However, on line research and enquiries indicate that the whole sale value of pine wood chip or pellets for biofuel currently offered by some suppliers ranges from $400 - $600 per tonne. Therefore, for this case study the authors assume that the cost of the woody biomass feed stock is about 10-15% of this figure i.e. $40 - $90 per tonne. If this value is applied to the 22,450 tonnes of eucalypt woody biomass, then the gross value of woody biomass for use as solid biofuel is estimated at $0.9 - $2 million/yr.

3.6 Extracting bioproducts from eucalypt residues

3.6.1 Essential oils

The foliage of *E. bosistoana* contains essential oils in quantity and quality suitable for commercial extraction that provide could support a small economically viable regional business. Essential oil production could improve the economic viability of growing *E. bosistoana* plantations and diversify a grower's income.

A study undertaken by NZDFI assessed the economic potential for essential oil production from New Zealand grown *E. bosistoana* plantations[63], with encouraging conclusions. A sensitivity analysis indicated that uncertainty of leaf biomass availability, genetic as well as seasonal changes in oil content, and fluctuations in essential oil price are equally important in determining the viability of an essential oil operation.

A small-scale essential oil producing business could potentially be sustainably supplied with foliage from the harvest of early trials and planting of *E. bosistoana.* This could then expand from around 2045 if forests are planted and the scale of harvesting increases.

E globoidea is unlikely to be a source of essential oils as it is low in oils.

(It is noted that in north Otago the forestry company Port Blakely permits a small business to collect Douglas fir needles and extract the essential oil.)

3.6.2 Bark extracts and bark products

Eucalypt bark is a natural insulator and has some fire resistance[64], but to date no commercial products have been developed that take advantage of these natural properties. Compounds in bark include biochemicals offering antioxidant, antibacterial, waterproofing properties and other uses. The prospect of extracting these high value chemicals is the focus of the Scion Bark Biorefinery Project[65] in Rotorua. The bark biorefinery promises to deliver significant quantities of water-repelling (hydrophobic) polymers. Hydrophobic polymers are used in items from paper coffee cups and rainwear to touch screen coatings. The market is dominated by petrochemical-based polymers but bio-based hydrophobic polymers are part of a rapidly growing market niche.

E globoidea and *E. bosistoana* have bark with very different characteristics. Together the bark of both trees would be a difficult material to use directly as a solid biofuel, but processing the bark to extract biochemicals may be a useful precursor treatment to subsequent briquetting to produce a solid biofuel.

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[63] Economic potential of essential oil production from New Zealand-grown Eucalyptus bosistoana | Scientific Reports (nature.com)

[64] Why eucalypts are survival experts | AusGeo (australiangeographic.com.au)

[65] https://www.scionresearch.com/science/bio-based-products-and-technologies/bark-biorefinery

Another option could be the development of a mulch with grape marc (Section 3.5.6.4). However, there has been no research on the bark of these species and this could be the focus of a future project.

3.7 Current national and regional policy and regulations relevant to case study

This case study proposes the establishment of over 5,000ha of durable eucalypt plantations across the Marlborough region between 2025 and 2055 followed by investment in two regional processing hubs. However, there are significant challenges facing the forestry sector to maintain and/or improve its social license to operate and regulations can be barriers to both planting new forests and establishing new processing hubs. Therefore, a short review of New Zealand's current regulatory environment has been undertaken.

3.7.1 Emissions Reduction Plan requirements

New Zealand's first emissions reduction plan was produced by the Ministry for the Environment in 2022. This contains strategies, policies and actions for achieving New Zealand's first emissions budget, as required by the Climate Change Response Act 2002. In doing so, the plan also outlines how the government planned to contribute to global efforts to limit warming to 1.5˚C above pre-industrial levels.

Some of the activity areas relevant to this case study include:

- supporting businesses to improve energy efficiency and move away from fossil fuels, such as coal, by continuing to roll out the Government Investment in Decarbonising Industry fund
- banning new low- and medium-temperature coal boilers and phasing out existing ones
- introducing an emissions pricing mechanism for agriculture
- reducing the amount of waste going to landfills, investing in waste infrastructure and expanding landfill gas capture
- accelerating the supply of woody biomass to replace coal and other carbon intensive fuels and materials.

With the change of government in 2023, some of these activities (for example, introducing a pricing mechanism for agricultural emissions) have already been side-lined. A second plan covering the period 2026-2030 is due to be published at the end of 2024[66]

3.7.2 National Environmental Standards – Commercial Forestry

The National Environmental Standards for Commercial Forestry (previously Plantation Forestry, NES-CF) are regulations made under the Resource Management Act (RMA) 1991[67].

The regulations provide a set of nationally consistent rules for commercial forests that cover eight broad activities, from planting right through to harvesting. This includes plantation forests and exotic continuous cover forests. Durable eucalypt forest will be covered by the NES-CF.

The NES-CF is implemented by regional councils and district councils. Councils can make additional rules as they deem necessary to protect the regional environment. All planting, managing and harvesting operations must adhere to the NES-CF and any local variations.

3.7.3 Marlborough regulatory environment: the Proposed Marlborough Environment Plan and management of commercial forestry activity

The Proposed Marlborough Environment Plan (PMEP) was publicly notified in 2016 with decisions on submissions publicly notified in February 2020[68, 69]. Most provisions within the PMEP can be treated as operative, as most appeals have been resolved. There are two outstanding appeals on the forestry provisions, but these are specific to significant natural areas and relate to potential additional controls only. The PMEP replaces the operative Wairau/Awatere Resource Management Plan and the Marlborough Sounds Resource Management Plan.

[66] Emissions reductions | Ministry for the Environment
[67] https://www.mpi.govt.nz/forestry/national-environmental-standards-commercial-forestry/
[68] Pers com, Pere Hawes, Manager, Environmental Policy, Marlborough District Council'.
[69] Proposed Marlborough Environment Plan - Marlborough District Council

Commercial forestry in Marlborough predominantly occurs within the Coastal Environment Zone (the rural environment in the Marlborough Sounds) and the Rural Zone (the rural environment in South Marlborough). Each zone contains rules that control activities occurring within the zone, including the planting, harvesting and replanting of commercial forestry and the processing of the commercial forestry crop (as an industrial activity).

3.7.3.1 Regional regulation of planting, harvesting and replanting under the National Environmental Standards for Commercial Forestry

In the Rural Environment Zone, commercial forestry is predominantly managed through the provisions of the National Environmental Standards for Commercial Forestry 2023 (NES-CF). The NES-CF establishes the status of planting, harvesting and replanting activities (whether the activity is permitted or requires resource consent) and establishes appropriate standards for those activities.

Most commercial forestry planting, harvesting and replanting in the Rural Environment Zones is a permitted activity under the NES-CF. The Council has placed additional controls on commercial forestry planting in terms of the proximity of the planting to significant wetlands and to abstraction points for registered drinking water supplies, planting in 'flow sensitive' sites (mapped in the PMEP) and planting in the Limestone Coastline Outstanding Natural Feature and Landscape and the Wairau Dry Hills High Amenity Landscape (mapped in the PMEP) (see Standards in 3.3.6 of the Rural Environment Zone).

These are all matters that the NES-CF allows Council to have more stringent controls on or are matters beyond the scope of the NES-CF. Planting within the setbacks and within the sites/landscapes identified above requires resource consent. There are also additional standards for harvesting in the PMEP to those in the NES, related to proximity to wetlands and water quality (see 3.3.8 of the Rural Environment Zone).

In the Coastal Environment Zone, the Council made the decision in 2017 to exercise stringency with respect to the NES in order to manage the potential for sedimentation and the potential adverse effects on significant wetlands, the Marlborough Sounds landscape and on registered drinking water supplies. Planting, replanting within 200 metres of the coastal marine area, and harvesting of commercial forestry in the Marlborough Sounds, is a restricted discretionary activity under Rules 4.5.3 and 4.5.4 of the Coastal Environment Zone. The matters of discretion are limited to the purposes set out above (i.e., Council cannot take into account other matters in its consenting decision-making process). This means a resource consent is required to undertake these activities. There is a long history of commercial forestry being managed under resource consent in the Marlborough Sounds that significantly predates the PMEP.

3.7.3.2 Regulation of sawmilling and wood processing

The PMEP provides industrial zones within which industrial activities can occur as a permitted activity. Sawmilling and wood processing in most circumstances are considered to be heavy industry and heavy industry is provided for in the Industrial 2 Zone. There is zoned 'green fields' i.e. undeveloped land that is zoned in the PMEP as Industrial 2 at Riverlands Industrial Estate and at Burleigh. Existing industrial sites zoned Industrial 2 could also be utilised for processing. In both circumstances, there are plan standards that must be complied with including the management of nuisance effects (such as noise, lighting, particulate and dust) (See 12.2.1 to 12.2.10 of the Industrial 1 and 2 Zone).

The PMEP also provides for activities to be established in the Rural Environment Zone through provisions managing "rural industry". These provisions contemplate industrial processes occurring in the rural environment to support the rural sector and the use of rural resources. Rural industry requires a resource consent under Rule 3.6.7 of the Rural Environment Zone. The suitability of a site for a proposed rural industry will depend on the nature of the rural industry and the compatibility of the activity with the surrounding rural environment. There is specific policy within Volume 1, Chapter 12 to guide this determination.

Timber processing predominantly occurs at the One-Forty-One site at Kaituna. This occurs on land zoned Rural Environment and the site has been developed over the years through resource consent processes.

3.7.4 The Emissions Trading Scheme and other greenhouse gas-related policies

Relevant policies or legal obligations applying to landowners with an interest in using trees to offset emissions, the most influential current policy is the NZ Emissions Trading Scheme (ETS)[70].

3.7.4.1 Agriculture's greenhouse gas emissions

Agriculture's greenhouse gas (GHG) emissions, which make up over 55% of national greenhouse gas emissions, remain external to the ETS and any other emissions accounting scheme at present. 2025 was set as the date when farmers would have to become accountable for their GHG emissions in some way by the previous Labour government; the new coalition government has rejected this approach. Methane (CH_4) emissions from ruminants – predominantly dairy and beef cattle, and sheep – comprise by far the biggest proportion of agriculture's direct or 'Scope 1' GHG emissions[71]. Nitrogen-based fertilisers and animal manure are also important as they break down to emit nitrous oxide, N_2O - another GHG. Crop production is responsible for a much lower proportion of agricultural emissions - fuel, fertiliser and agri-chemicals are the main sources of direct crop production emissions and these emissions are predominantly CO_2. Heat and power required for on-farm processing such as drying is a 'Scope 2' type emission.

An industry/government partnership, He Waka Eke Noa, which included all the main agricultural sectors, was working to develop a scheme for agricultural emissions accounting, which included looking at ways to account for existing tree cover on farms which is currently ineligible for the ETS. This initiative has now been abandoned. One on-going area of contention is the way methane is accounted for as a GHG, and how to correlate sequestration of CO_2 by trees with methane emissions. A report by the Parliamentary Commissioner for the Environment report provides more information on this complex topic[72].

Grape growers are also exempt from any compulsory GHG auditing at present. The main emission sources from vineyards are nitrogen fertilisers, chemical sprays and fossil fuels. Wine-making requires power for various processes, plus bottles and other packaging within the winery gate. The vineyard and wine-making industry, conscious of its international market reputation, has been proactive in assisting its members to estimate their GHG emissions and look at ways of mitigating them. The industry organisation 'Sustainable Winegrowing New Zealand' has led this activity[73].

3.7.4.2 Forestry in the ETS

Plantation forestry is a complex proposition in terms of its impact on GHGs because of the cycle of carbon storage while trees are growing, partial loss when the trees are harvested with further losses over time as roots and other biomass left on site break down, and storage of some sequestered carbon long-term in harvested wood products. Also, and only recently, emissions associated with management and particularly forest harvesting operations are being evaluated.

Forestry has been an essential participant in the NZ Emissions Trading Scheme since it was launched in 2008. The ETS is a voluntary scheme. ETS eligibility depends predominantly on the land-type and planting date of the forest. Eligible forests must be planted on land which did not have tree cover before December 31st 1989 – in other words, they are 'post-1989' forests. They must be at least one hectare in size, have a minimum crown cover (or potential crown cover) of 30%, and be over 30 metres wide.

Forest owners with post 1989 forests in the ETS receive carbon credits called New Zealand Units (NZUs) related to the annual amount of carbon sequestered by their trees while growing. Standard ETS look-up tables are used for forests under 100ha, whereas forests over 100ha are measured via a network of plots, and participant-specific tables are generated under a system called the Field Measurement Approach (FMA)[74].

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[70] https://www.mpi.govt.nz/forestry/forestry-in-the-emissions-trading-scheme/
[71] FGR Technical Report H060: *Carbon footprint of harvesting operations in New Zealand:* https://fgr.nz/documents/download/10587?161537090 for discussion and references about how emissions are measured.
[72] https://pce.parliament.nz/publications/how-much-forestry-would-be-needed-to-offset-warming-from-agricultural-methane/
[73] Sustainable Winegrowing New Zealand (2022) *National Greenhouse Gas Emissions and Energy Use Report* https://www.nzwine.com/media/22253/nz-winegrowers-sustainability-report-2022.pdf
[74] https://www.mpi.govt.nz/forestry/forestry-in-the-emissions-trading-scheme/emissions-returns-and-carbon-units-nzus-for-forestry/calculating-the-amount-of-carbon-in-your-forest-land/carbon-tables-for-calculating-carbon/

Forest owners who entered the ETS prior to 2022 are generally registered under the 'stock change' system, which means NZUs are accumulated while the trees are growing, and then a large proportion must be paid back at harvest. From 2022 onwards, new entrants can only register under an 'averaging' system, where the average amount of carbon stored in their crop over infinite rotations is allocated in the first rotation, no liabilities are incurred at harvest, and no further allocations are made.

In the case of durable eucalypts under 100ha, the relevant look-up tables are the generic, nationwide 'exotic hardwood' tables. These tables were originally formulated based on the growth rate of *E. nitens* - a non-durable eucalypt which grows relatively fast in the first 12-15 years and for which good New Zealand growth data is available. The average age allocation for all exotic hardwoods in the ETS has been set at 12 years; the standard amount of carbon allocated for these species is 320 NZUs/ha.

(In contrast, the use of the plot level models using PSP data for the individual case study properties provides much more accurate regional estimates of growth for the two durable eucalypt species concerned – *E. bosistoana*, and *E. globoidea*. See Part 2 of this report for more details.)

Forests that are on 'pre '1990' land – i.e. land that had some sort of tree cover before Jan 1st 1990 - are ineligible for carbon credits under the ETS. This includes natural forests as well as plantations. Extensive areas of Marlborough plantation forests were planted before 1989. Many small and scattered areas of trees on farms, including erosion-control plantings are also ineligible for the ETS. There are also extensive areas of regenerating natural forest (land that was cleared but is now reverting to natural forest) which are ineligible because they do not meet 'post 1989' criteria. However, some Marlborough landowners do have extensive 'post '89' areas of natural regeneration which are registered as permanent forests and generate small but steady amounts of NZUs per hectare.

When plantation trees are harvested, much of the carbon is deemed to be released and in accounting terms is an emission from that land-holding.

In the case of pre-1990 forests, no more than 2ha/yr can be felled and not replanted (but this is not relevant to any carbon accounting, as these older forests are external to the ETS).

Forest owners in the ETS do not have to account for emissions generated by forest management and harvesting operations such as emissions from vehicles and machinery. Many New Zealand forests are certified under one or more international certification scheme – e.g. FSC or PEFC – but these schemes do not yet require any formal emissions (or sequestration) accounting. Some of New Zealand's larger forest owners are now embarking on more active corporate social responsibility activities such as setting sustainability targets and reporting on progress to stakeholders, and this can include life-cycle analysis of their total forestry activities (i.e. Scope 1, 2 and 3 analysis).

The use of biomass from forestry as a biofuel is considered near carbon neutral provided the harvested trees are replanted[75]. The fossil fuels used by forest management vehicles and harvesting machinery prevent biofuel from being considered fully carbon neutral.

3.7.4.3 Using trees to offset agricultural emissions

Farmers wanting to directly offset their livestock emissions by planting trees cannot currently do this within the ETS. One purpose of He Waka Eke Noa was to find a way for farmers to be able to include existing woodlots and regenerating areas, or new tree plantings, in their emissions accounting, thereby reducing liabilities from livestock emissions if and when agriculture is brought into the ETS or a new carbon accounting mechanism is established.

Whether or not using trees to offset emissions is a valid approach in terms of any real contribution to mitigating global warming remains open to debate:

'Offsetting with trees should be a last resort that is used only when all practicable means of reducing emissions at source have been exhausted. If forestry is used to offset livestock methane, it should only be used in addition to – not instead of – gross emissions reductions. The Climate Change Response Act 2002 requires a reduction in biogenic methane emissions of 24–47% by 2050 relative to the 2017 level. Forestry offsets could be used to go beyond whatever minimum gross reduction within this range proves possible. The existing architecture of the Climate Change Response Act does not

[75] https://www.bioenergy.org.nz/resource/tnbb18-bioenergy-is-carbon-neutral

allow forestry offsets to be counted towards national targets for biogenic methane. Therefore, changes to the architecture of the Act would be required if this were to be considered.'[76]

Regardless of whether or not their land and enterprises are eligible for the ETS or any other scheme, many primary producers would like to be able to claim to be at least 'carbon neutral' and/or to be operating under sustainable principles (and certified as such where possible). This is because of actual or perceived marketing advantages as well as satisfying personal ambitions to run enterprises in an environmentally benign way.

4 De-risking through science: NZDFI's breeding, research and development work

This case study is underpinned by the research and development undertaken by NZDFI since its inception in 2008. NZDFI's science-based strategy has been successful in getting effective collaboration with multiple people and agencies including landowners that host a network of over 40 trials on a range of land-types, both on farms and in forests[77]. The outputs from a fifteen-year-plus research and development programme include:

- breeding improved planting stock of a range of durable eucalypt species
- planting and measuring demonstration trials to develop site/species information, proving guidance on how to select, establish and grow these species. Three of these demonstration trials are in Marlborough, along with a further eight breeding trials.
- developing growing regimes and models to suit varied environment conditions and provide different products
- researching wood quality, processing, products and markets
- developing the concept of wood supply catchments centred on future processing industries
- exploring and promoting multiple markets for durable eucalypt timber.

NZDFI's four main research themes are all essential for the development of a successful durable eucalypt industry (Fig 9):

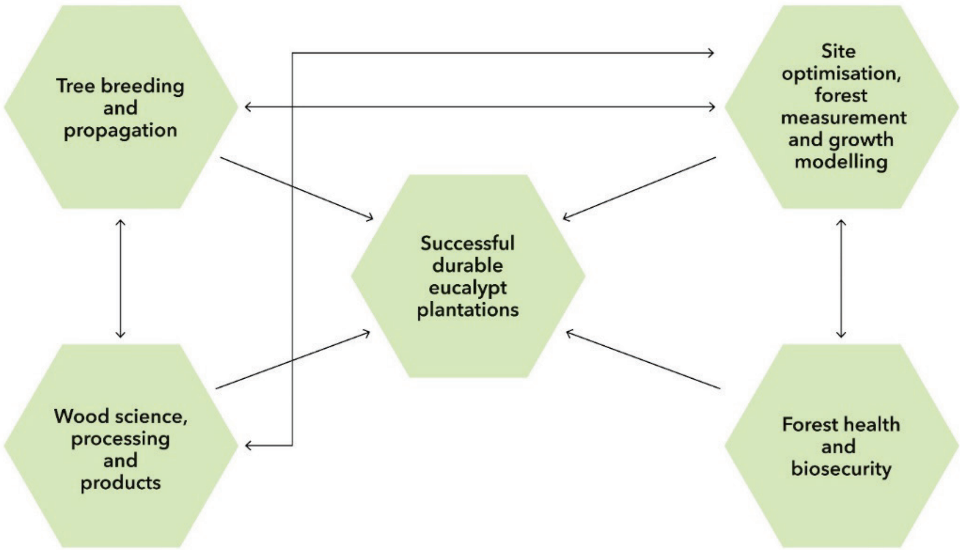

Fig 10: NZDFI's four main research themes.

These research activities are reported in detail in the 'Our Science' section of the NZDFI website and in NZDFI's six-monthly Project Update newsletters[78]. A short summary is provided below.

[76] The Parliamentary Commissioner for the Environment (2022): *How much forestry would be needed to offset warming from agricultural methane?* https://pce.parliament.nz/publications/how-much-forestry-would-be-needed-to-offset-warming-from-agricultural-methane/
[77] https://nzdfi.org.nz/trial-sites/
[78] https://nzdfi.org.nz/

4.1 Tree improvement work including breeding and demonstration trials

Growers need to have confidence that their investment in new planting is going to be economically rewarding. Good quality nursery stock is essential - plants of known genetics and proven potential. Before the NZDFI's breeding programme began, durable eucalypts planted in New Zealand were unimproved – i.e. they were grown from seed collected from natural Australian forests or were the progeny of early New Zealand plantings.

NZDFI's major long-term focus is the production of superior genetic material for large-scale deployment, leading to the establishment of a major new hardwood resource in New Zealand. This approach is based on applying rigorous well-proven scientific methods, combined with innovative technology. There is a lot of genetic diversity in all tree species so significant gains in selected traits are possible. NZDFI has been making rapid gains by extensive sampling of large tree breeding populations and Proseed NZ has successfully established clonal seed orchards.

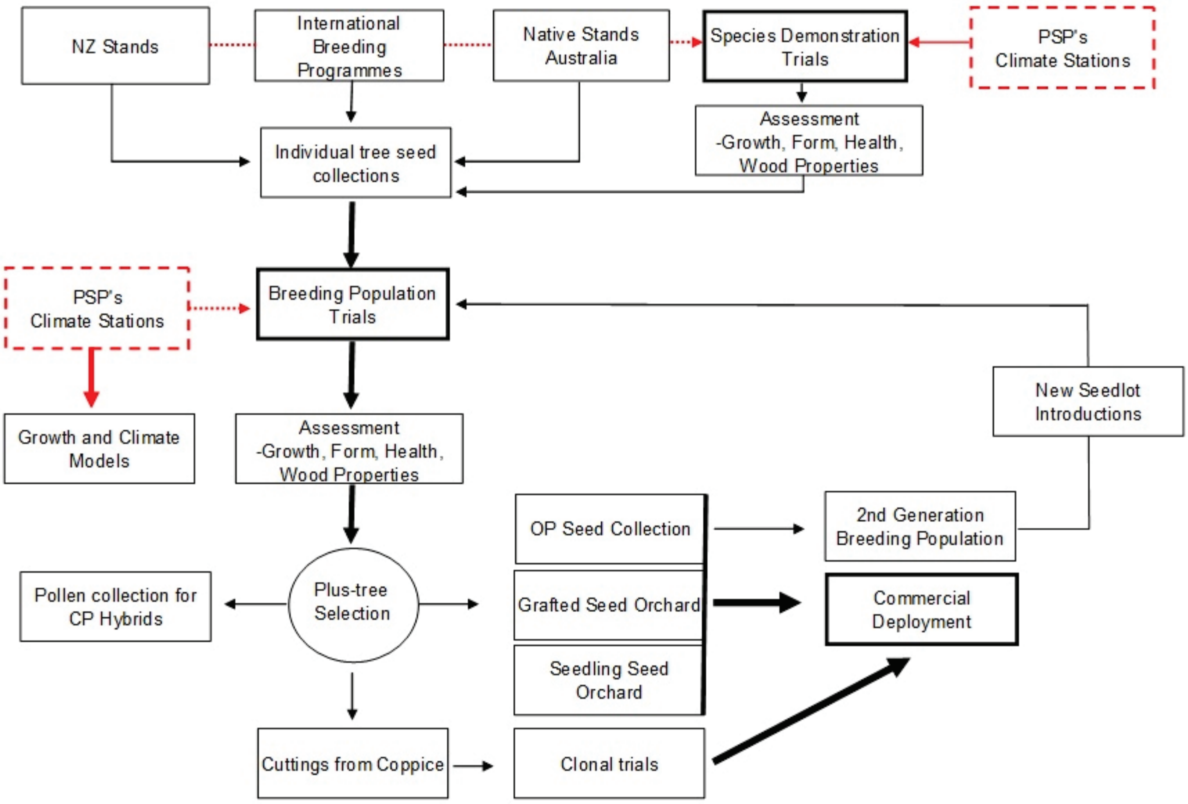

Fig 11: The NZDFI tree improvement programme.

The two primary species which are the focus for tree improvement work are:

- *E. bosistoana* Coast grey box
- *E. globoidea* White stringybark

Secondary species identified from extensive trials that have had some genetic improvements are:

- *E. cladocalyx* Sugar gum
- *E. macrorhyncha* Red stringybark
- *E. quadrangulata* White-topped box gum
- *E. tricarpa* Red ironbark

NZDFI began by working with a relatively large range of species to reduce the risks associated with certain species vulnerability, for example, to frost, pests and diseases. Major breeding efforts are focused on *E. bosistoana* and *E. globoidea* at present but as resources allow further species can be added to the breeding programme.

Some of the species were selected partly on performance in earlier New Zealand trials; others were chosen specifically for their timber properties or ability to hybridise. All species meet the following criteria:

- Class 1 or 2 durability (Australian standard)
- Good growth
- Good stiffness and strength properties
- Drought resistance
- Relatively good frost tolerance
- Established timber potential from experience in Australian markets.

4.1.1 NZDFI trial network

Since its foundation in 2008, a fundamental part of NZDFI's work has been to establish a network of trials. Two types of trials combine to form the total trial network:

- **Breeding trials** – trials which contain the base breeding populations for genetic selection of the key species identified for a durable hardwood industry in New Zealand. NZDFI has large breeding trials of *E. bosistoana* and *E. globoidea.*
- **Demonstration trials** – trials that test the adaptability and productivity of a broad selection of durable eucalypt species. Eleven different species were initially selected for testing in New Zealand conditions.

The genetic origin of every tree planted in NZDFI breeding trials is known and recorded in a meta-database. Individual trees from every family are carefully labelled: every tree can be tracked from the nursery to its planting site. Site maps provide a record of the exact planting location of every tree. This genetic information and tracking are an essential element of NZDFI's tree-improvement programme.

Also essential is the large network of permanent sample plots (PSPs) which have been set up in the trials – these PSPs are measured regularly to provide robust data on the performance (survival, growth, form, tree health etc) of different species on different sites. Recent full analyses of PSP data have been completed, and two reports produced, providing the best information to date on species productivity and to assist with site/species matching.[79,80]

4.2 Site characterisation, growth and yield modelling

Understanding the specific site requirements of different eucalypt species and combining this information with accurate measurement of different species' productivity on different site types are essential parts of NZDFI's research programme.

The UC/NZDFI Science team have been developing growth, heartwood volume and total bio-mass models for two key species, *E. bosistoana* and *E. globoidea.* This SLMACCC project has enabled further development of these models (see Section 3.1).

In addition, an integrated approach of combining destructive-sampling-based ground measurements with UAV data and using algorithms and statistical methods has been successful in estimating AGB and DBH at individual tree level for NZ plantation grown *E. bosistoana* and *E. globoidea.* This approach could be extended to other forestry species in other NZ regions.

Publications have been submitted for both these research outcomes[81, 82] and more details are available on the NZDFI website[83].

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[79] Variation in adaptability and productivity between durable eucalypt species in different New Zealand environments - SWP Technical Report T164 (July 2023)
[80] A comparison of the performance of six eucalypt species planted in 2018 NZDFI demonstration trials. - ITP Technical Report T013 (October 2023)
[81] *Individual tree biomass sampling of durable eucalypts (June 2024)*: Report submitted to MPI as part of this SLMACC project.
[82] *Individual tree biomass estimation of durable eucalypts using LiDAR (November 2023)* Report submitted to MPI as part of this SLMACC project.
[83] Site characterisation, tree measurement & modelling - https://nzdfi.org.nz/our-science/site-character-tree-measurement-modelling/

4.3 Wood quality and durability research

NZDFI aims to breed trees that will yield consistently high quality, durable timber. Wood, like all natural products, is highly variable. Previous research has revealed that wood properties are partly controlled by genetics. By breeding from trees with superior wood quality properties, significant gains in overall wood quality can be made.

Research at the School of Forestry has focused on developing knowledge and understanding of the wood properties of durable eucalypt species, and their heritability. Also, the variation in quality and quantity of heartwood produced at different ages and on different sites. Further research on hardwood processing, product development and markets has also been undertaken.

All these research outcomes have been applied in NZDFI breeding programme with significant genetic gains captured by Proseed's work to propagate their 1st generation clonal seed orchards for *E. bosistoana* and *E. globoidea*.

From 2017-2023, wood quality research at the School of Forestry was supported by the Specialty Wood Products Research Partnership (SWP), a seven-year research partnership managed by Forest Growers Research. The School of Forestry team has produced over 20 technical reports[84] as well as numerous journal articles and popular publications[85].

4.4 Tree health research

NZDFI's eucalypt health research focuses on the impacts of several Australian eucalypt insect pests that are established in New Zealand. Their impact is very variable with some species being heavily browsed while others are much less so. There is also significant seasonal variation and variation between regions and sub-regions. While severe insect browse is reducing tree growth on some sites, on other sites the impact on tree productivity is minimal. More knowledge about tree health will enable growers will be to match species to site including consideration for pest tolerance.

Tree health researchers at the School of Forestry have also made some progress with research to identify the tolerance of different durable eucalypt species to insect pest browse. These pests include *Paropsis charybdis* (the eucalyptus tortoise beetle) and the recently arrived *Paropsisterna cloelia (*eucalyptus variegated beetle EVB). The research has involved a significant monitoring programme within NZDFI's trial sites, quantitatively assessing pest life cycles and pest damage, and other insect parasites of these pests. The outcome has been to identify the most susceptible species. A report summarising this research is available[86]: Further work is needed to optimise tree health through correct site species matching.

Recent UC PhD research to investigate the phenology and natural enemies of *Paropsisterna cloelia* and *Paropsis charybdis* in Marlborough is due for completion in the near future. This project has involved extensive field work at two of NZDFI's Marlborough trial sites and this will inform further work on the biological control options for the two main eucalyptus beetle pests in south Marlborough.

5 Conclusion

Overall, this regional case study highlights that developing a durable eucalypt supply chain will require long term regional planning, collaboration and investment in landowners planting genetically improved trees through to processors marketing durable hardwood products. The study provides evidence that a durable hardwood industry could annually produce over $90 m in regional GDP; diversify the region's economy; deliver financial and environmental outcomes to farmers, forest owners, grape growers and wine makers; and create new employment in the forestry and wood processing sectors.

The project makes a valuable contribution to providing a market- and science-based pathway for developing a sustainable durable hardwood industry and supply chain in Marlborough. NZDFI have identified there are many North Island regions that have potential to grow durable eucalypt forests and where further regional case studies could be undertaken.

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[84] SWP Technical Reports: Wood Quality Research - NZ Dryland Forests Innovation (nzdfi.org.nz)
[85] Peer-reviewed & popular publications - NZ Dryland Forests Innovation (nzdfi.org.nz)
[86] SWP T140: Eucalyptus resistance to paropsine beetles (December 2021).

Appendix 1: Species selected for Marlborough forest regimes

The following section provides details of the three species NZDFI has identified as being most suitable for large-scale planting in Marlborough. More details of all three are available on the NZDFI website[87, 88, 89].

Eucalyptus bosistoana

NZDFI selected *E. bosistoana* for its breeding programme based on broad environmental adaptability and the published Australian record of its use as a class 1 durable light-coloured brown/pink heartwood. This made it suitable for a wide range of applications and NZDFI identified its potential to produce vineyard posts with in ground use expected to exceed 25 years. However, there has been no previous forestry research of this species potential in Australia and New Zealand.

Between 2009 and 2021 NZDFI established 11 progeny trials to test a total of 247 open-pollinated seedlots collected from across the native range of the species in Australia. It also successfully established this species in 22 demonstration trials between 2011-2018. Across all of these trials, this species has shown extremely variable stem form and branching habitat.

Assessments in the progeny trials revealed that the genetic parameters of growth, form and durable heartwood are under genetic control. Using near infrared spectroscopy to screen for durable heartwood, the top families and elite trees have been selected (Y. Li et al. 2020). These have been grafted and established in a clonal orchard by Proseed. Since 2021 this orchard has been producing genetically improved open-pollinated seed.

There are several of NZDFI's *E. bosistoana* trials in Marlborough. It has shown broad regional adaptability and productive growth rates across these trials including those assessed on the case study properties.

Notably, the highest regional productivity recorded is in one of the progeny trials planted on an alluvial site, located on the Marlborough District Council Cravens Road reserve. These were planted in 2009 and 2010 on a berm within the stopbanks of the Wairau River and have survived many flood events without significant damage. The trees are thriving in the alluvial silt/gravel with some elite trees exceeding 2m annual height increment.

The species can tolerate around minus six-degree frosts although late spring frosts can damage or kill seedlings. It has attained low to moderate productivity on a variety of other sites and can survive and thrive in seasonally wet sites with both light and heavy soils. It is not suited to dry exposed sites that reduce height growth and encourage poor form.

There are several introduced insect pests that can seasonally browse *E. bosistoana* foliage. These include leafroller (*Ctenopseustis obliquana*); eucalypt tortoise beetle (*Paropsis charybdis)* and the eucalypt variegated beetle, (*Paropsisterna variicollis).* Research by the University of Canterbury School of Forestry has identified genetic selection for browse tolerance is possible and that there are some NZ native predators of the eucalypt variegated beetle. Further work is required to develop and enhance these biological options.

Eucalyptus cladocalyx

While not a species selected for NZDFI's breeding programme, *Eucalyptus cladocalyx* has been tested in many demonstration trials due to its potential adaptability to dry hot exposed environments of New Zealand's northern east coast regions, particularly south Marlborough.

Eucalyptus cladocalyx produces a class 1 durable yellowish-brown timber that is hard, strong and termite resistant and it's use for posts, poles and general construction led to farm plantings from 1880's throughout South Australia and drier western areas of Victoria. There are only a small number of planted stands known in New Zealand as it had not been considered for forestry.

[87] E. bosistoana - NZ Dryland Forests Innovation (nzdfi.org.nz)
[88] E. cladocalyx - NZ Dryland Forests Innovation (nzdfi.org.nz)
[89] E. globoidea - NZ Dryland Forests Innovation (nzdfi.org.nz)

The Australian Low Rainfall Tree Improvement Group (ALRTIG) breeding programme was established in 1999 to work on potential forestry species to grow on a 20-year rotation in dryland south-eastern Australian sheep-wheatbelt regions with 400-650 mm annual rainfall. A recent report summarising Australian trials reported that *E. cladocalyx* was measured in 50 plots at five low rainfall (400-700mm annual rainfall) sites with a range of ages. Data analysis showed this species had a range of site productivity with moderate to high productivity sites recording an annual volume increment of 5-7 cubic metres per hectare.[90]

The ALTRIG project tested *E. cladocalyx* and found that it can produce dense durable wood at a young age. While no full genetic evaluation has been made of wood properties, some families develop durable heartwood by age 8-10 years (Bush 2011). 1st generation improved seed for growth and form has been produced from this breeding programme and is the seedlot deployed by NZDFI in all of the demonstration trials.

It has proven to be one of the most frost sensitive of the NZDFI species with losses in the winter following planting and at a few sites, there was almost total block failure. It is also intolerant of poorly drained heavy soils. Otherwise, where it has been successfully established, it has grown vigorously particularly on drier sites with limestone or sedimentary derived soils where it has produced the highest MTHAI. It has been particularly successful on dry exposed south Marlborough sites. However, on higher rainfall sites with higher humidity it has performed poorly.

At most demonstration trial sites there is little insect browse or diseased foliage evident. Although the trials were planted with a 1st generation seedlot there is still considerable variability in tree form. Young trees may develop double leaders that form pruning can correct. Otherwise, the species self-prunes with the best trees developing straight clear stems with a moderately large, rounded crown.

Eucalyptus globoidea

Eucalyptus globoidea is used in Australia for general construction due to its class 2 durable straight grained light brown occasionally light pink heartwood. *E. globoidea* is found throughout eastern New South Wales except the far north, and eastern Victoria. On optimal sites it can reach heights of 25 – 30m and 1m diameter.

It was an early introduction to New Zealand with many older farm forestry plantings in Northern regions and an impressive stand at Little River on Banks Peninsula, Canterbury that is now over 100 years old. The former NZ Forest Service successfully planted several stands in their Bay of Plenty and Northland forests. It was popular with some farm foresters and was one of the eucalypt species recommended by Neil Barr.

Early assessments in both NZDFI progeny trials and demonstration trials recorded good survival, early growth and wide site adaptability. Seedlings have grown rapidly on sheltered, higher rainfall and fertile sites however moderate frosts and waterlogged soils resulted in total failure at one site.

The mean top height mean annual increment (a measure of annual growth) measured in the demonstration trials is 1.3m, 0.2m higher than any NZDFI species. The highest productivity was on Hawkes Bay sites with limestone derived soils and sites with higher rainfall and pumice soils. On sites with low rainfall (under 600mm), productivity is significantly reduced. The NZDFI South Island trials are on drier and cooler sites than those in Hawkes Bay, Gisborne and Central North Island.

Across all of these trials and even more so in NZDFI's progeny trials, this species has shown extremely variable stem form and branching habitat. In some demonstration trials early form pruning was undertaken to correct this.

Trees grown from the seed collected in the clonal seed orchard will have improved productivity and stem straightness, branching habit, heartwood content and durability.

E. globoidea has not been heavily browsed by insect pests at any trial sites and was reported one of the least impacted by seasonal browsing.

[90] Trials Review, Information and Genetics Project (TRIG) Report 1 of 3 (2023) Produced by PF Olsen for Forestry Australia

Appendix 2: Additional information on woody biomass and solid biofuel products

Models for solid biofuel supply
Generally, it is not efficient for farmers and small woodlot owners to individually contract to supply residues as solid biofuel to end users. They are most likely to contract to a contractor or biomass aggregator to remove residues after shelterbelts, or their woodlot, has been harvested. In some regions the farmers or small woodlot owners have created a collective entity to collect residues and supply under a collective contract to end users.

Acting collectively provides economies of scale for a biomass aggregator to invest in residue collection and chipping equipment. The aggregator manages the flow of biomass from the respective farms under a long-term collective harvest plan.

Sale and supply of solid biofuel requires that the biomass residues collected either at harvest or from wood processors is upgraded to meet the customer's boiler fuel specification.

Biomass cannot be collected at the time of harvest and delivered directly to customers as solid biofuel because the wood is 'green' and needs drying to reduce the moisture content to that required for full combustion.

Whole tree harvesting requires being able to efficiently breakdown the tree into post and log lengths from the main stem with the upper stem wood, branches and off-cuts of short or misshapen lengths recovered separately for biomass. (For one durable eucalypts species*, E.bosistoana,* the recovery of leaves for oil extraction is an option.)

Woody biomass needs drying and processing into fuel. There are two options;

- stacking and drying at the forest site followed by a portable chipper that can produce suitable boiler fuel for direct delivery to the customer.
- alternatively, the biomass is transported to a wood fuel supplier's hub where it is dried and upgraded to meet specific contract specifications.

In both cases sieving out under and oversized material, removing non-organic material, and drying to the specified moisture content is required. Fuel that does not meet specification will result in lower energy conversion efficiency and potentially pollution from incomplete combustion.

It is likely that the highest value to forest growers is achieved if residues are stacked and stored in the forest post-harvest for air drying and collection when required. This regime reduces the solid biofuel supplier's cost for storage and minimal upgrading may be required.

Few forest growers can set themselves up to be a solid biofuel supplier as wood fuel preparation and supply is a specialist business and to be a supplier requires significant capital investment in equipment for chipping, drying and transport of the solid biofuel and the need to develop long term supply contracts. No information on the cost of setting up as a solid biofuel supplier is available as these operations can develop as a small start-up using a single chipper and expand as business grows to include drying and sieving equipment and a larger chipper. Many solid biofuel suppliers have developed this business as an adjunct to an existing business e.g. agricultural contracting, or sawmilling.

Most forest growers will contract to specialist solid biofuel suppliers with end user contracts and the capability to aggregate biomass from different sources to reliably and consistently meet fuel purchase contracts. Maintaining a steady source of biomass can be difficult and requires that a supplier can purchase from a network of forest growers.

Consolidation of all regional biomass sources (pine and eucalypt) is possible if a site can be established to aggregate the supply. The size of a regional hub would be up to 3 ha to allow space for log and processed biofuel storage and could ensure economies of scale. The actual area required would be influenced by how much portable chipping systems can be utilized in the forest to create a direct supply to users and how much log storage is required where this is being dried on site.

Sale of woody biomass to solid biofuel suppliers
One of the products that a forest grower could offer to a specialist solid biofuel supplier are forest biomass residues for aggregation with other sources. The supplier processes the biomass residues into solid biofuel that meets the customer's fuel specification and sells and delivers the solid biofuel to customers.

For residues sourced from forests, ideally a grower can contract to sell the biomass on a chipped basis by weight with the purchaser doing the collection, chipping and transport to a weigh bridge for measurement. The point of transfer of ownership of the wood biomass is generally at the point of collection.

The Forest Growers Levy applies to woody biomass supplied from a plantation forest. The solid biofuel supplier who removes the residues beyond the forest gate is required to provide Levy System Limited details of the woody biomass removed from the forest on a monthly basis. Levy System Limited sends a levy invoice to the forest owner.

Suitability of eucalyptus as a wood fuel
Biomass differs by species and while all biomass can be suitable as a fuel the characteristics of the solid biofuel needs to match specific boiler characteristics. This can require testing and /or boiler tuning depending on the design of the boiler.

As all eucalypts produce dense hardwood with a high calorific value, they are sought after to produce premium solid biofuel. This high energy fuel allows smaller sized handling equipment and storage area than for softwood fuels based on Radiata pine with lower capital cost for the same heat output.

Most boilers and their handling systems don't like stringy bark or peelings from eucalypts. For the biomass of each eucalyptus species to be utilized as a certified solid biofuel then some research may be required to understand how it combusts in a boiler[91]. There may be hogging equipment with blades which may be suitable or processing through a hammermill may be adequate.

Eucalyptus residues from wood processing can be densified into fuel pellets or briquettes but currently there is no information available on doing this. This requires future research are the supply chain expands and market demand for high quality bio fuel increases.

Wine sector own sourcing of biomass for heat
Where a business has access to a renewable energy resource from their own business it is generally most cost effective for them to produce their own energy from those resources. This is referred to as embedded energy. Vineyards and wineries in Marlborough use extensive amounts of electricity and this can be produced from solar photovoltaics with on-site battery storage. Theoretically by 2050 enough electricity could be produced by the wine industry from solar to meet 100% of their demand. For this case study it is assumed that biomass is not used to generate electricity.

Vine prunings could be used directly by the winery to produce their own heat, thus avoiding the need to purchase energy. However, most vine prunings are composted so biomass for heating needs to be imported to the winery. For this case study it is therefore assumed that all biomass from prunings, along with grape marc, is composted and used as a soil conditioner in the vineyards.

There are some grape growers that have land with the potential to grow durable eucalypts to produce their own posts. These may be able to establish smaller scale post peeling operations that they directly use on site. The residues could be used for on-site heating, or with innovation in the design of frost fans to run on wood fuel rather than diesel However, the use of durable eucalypts in close proximity to vineyards is to be avoided due to the risk they pose to taint the wine produced from the adjoining vineyard.

There is potential to use biodiesel to replace diesel in existing frost fans. Biodiesel can be produced locally in a similar manner to NZ Biofuels[92] are doing in Christchurch. Use of biodiesel in existing frost fans would result in no need for capital expenditure for replacing existing frosts fans or use of expensive helicopters.

Biomass and bioproduct terminology

- Above Ground Biomass (AGB) – generic term for the total volume of the trees - all logs, leaves, branches, short wood etc - produced in the forest and in theory available for processing into solid wood products, biofuel or biochemicals
- Biofuel – generic term to describe any fuel made from biological products
- Residues: (i) harvest residues are the branches, short log offcuts etc left in the forest or on the skid, after logs have been removed

[91] SRC eucalypt combustion, Altaner, Clemens and D Gong, CRL Energy, Short Rotation Crops for Bioenergy: New Zealand 2003, IEA Bioenergy.

[92] https://www.nzbiofuels.co.nz/

(ii) processing residues – all the offcuts, shavings, sawdust etc produced by sawmilling and remanufacturing

- Solid biofuel – woody biomass and residues that have been screened/further processed to produce a customer-ready product
- Biochemicals – products extracted from any type of biomass
- Bark is removed from logs when preparing them for processing. Bark removed during harvesting is difficult to recover and is normally left in the forest as a soil nutrient.
- Post peelings are the residues created from rounding up posts. Some peelings are thin and long in shape, making them difficult to handle. Additional processing may be necessary to create a more uniform product for solid biofuel use.
- Woodchip is created from small and misshapen logs, offcuts and can include branches. This can be sold for landscaping, animal bedding, MDF manufacture and as a quality boiler fuel. Biomass collected from forest harvesting is often referred to as hog fuel as it is likely to be produced by shredding and not chipping.
- Sawdust is a residue from log processing and one of the more difficult residues to sell. It may be mixed with other residues and sold as animal bedding. On site processing into wood pellets or briquettes is an option but needs capital for the equipment and the sawdust needs to be dried.
- Shavings are created when dressing the timber, which creates a finished product smooth and clean. Shavings are usually created after the timber has been dried so it is light and dry and is good boiler fuel.